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An Analysis of the Minerals Situation in the United States: 1989 — 2040

A Technical Document Supporting the 1989 RPA Assessment

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Resources Program and Assessment Staff

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INTRODUCTION: MINERALS AS A FOREST AND RANGELAND RESOURCE

HIGHLIGHTS:

* Minerals are essential to modern life.

* Minerals are important to the national economy and the economies of many states.

* Some minerals are of strategic importance, essential to national economic and military security.

* Minerals are different from other forest and rangeland resources in that they are more difficult to find, inventory, and develop.

* Mineral development is governed by a complex set of laws, involving a number of federal agencies in their administration.

Minerals are important forest and rangeland resources. The geological factors conducive to mineralization -- mountains and high elevations -- have deterred other uses, leaving the lands in forest and range. Defined as naturally occuring inorganic substances, some minerals are of simple composition, while others are combinations of two or more elements (Cameron 1986). Thus, minerals include coal and oil used for energy; metallic minerals such as lead, copper, and cobalt; precious metals and gems; and common building materials like sand, gravel, and clay. There are about 2500 minerals, some 100 of which are of world-wide economic importance.

Minerals play important and complex roles in our daily lives. If something we use is not made of plant or animal matter, it is made of minerals. More than 20 minerals are used in the construction of the typical home or office building. Thus a single building can use minerals produced by dozens of mines. Moreover, individual minerals are used in many different ways. For example,

the mineral spodumene is the source of lithium used in processing aluminum and manufacturing rubber, in glass and ceramics, television picture tubes, glass insulation, glazing flux, photochromic lenses, automobile headlights, specialty greases, and batteries.

Thus, every home or workplace has countless items made wholly or in part from minerals: kitchen ranges and refrigerators, cabinets and desks, computers and calculators; floor tiles and insulation; electrical wire and plumbing; glass, bricks, and cement; home tools and children's toys; medicines and cosmetics. Automobiles and trucks, airplanes and trains, subways and buses all are made of minerals and run on fuel from minerals. Minerals make possible high-tech telecommunications and high speed jet aircraft.

Minerals Are Different from other Forest and Range Resources

A number of factors distinguish minerals from other forest and range resources.

* Unlike other resources found on forest and rangelands, most (though not all) minerals are non-renewable and finite, the result of millions of years of geologic, biologic, and chemical processes.

* Minerals are far more difficult to inventory, explore, and develop than other forest and rangeland resources.

* Minerals are traded in global markets to a far greater degree than other forest and rangeland commodities, and governments intervene in the supply and prices of virtually all critical minerals.

* Because of their role in our economy, for energy, and in the manufacture of weapons systems, a number of minerals are of strategic importance to the United States and its allies.

* While the United States has abundant supplies of many minerals, it must depend on foreign countries for some of critical economic and strategic importance.

Minerals Contributions to the National and States' Economies

Minerals are major components of our national, state, and local economies. Nationally, the minerals industry contributed $122.8 billion to the gross national product (GNP) in 1985, with oil and gas extraction accounting for $96.4 billion, coal for $16.9 billion, and metallic minerals and minerals materials for $9.4 billion. Altogether, the minerals industry accounted for 3.1 percent of total 1985 GNP (U.S. Department of Commerce, Bureau of the Census 1986). Although the minerals industry's contribution to total GNP may seem small, they supply a large portion of the raw materials on which our economy depends. While the U.S. imports far more minerals than it exports, they still are a significant item in foreign trade; in 1985, non-fuel minerals sales overseas amounted to $13 billion, about six percent of the dollar value of all exports (U.S. Department of Interior, Bureau of Mines 1987a; U.S. Department of Agriculture, Bureau of Census 1986). Some 83.3 million short tons of coal worth $2.7 billion were exported in 1986 (U.S. Department of Energy 1987b).

Moreover, value added (calculated as receipts plus capital expenditures, minus production and shipping costs) by the mining industry in 1982 amounted to $188

billion, accounting for 40 percent of value added by all raw material industries, including agriculture, forestry and fishing (U.S. Department of Commerce, Bureau of Census 1984). In 1982, the last year for which Bureau of Census figures are available, some 73,000 establishments nationwide employed more than 1.1 million persons in mineral exploration, extraction and milling, with a payroll of $28.6 billion (U.S. Department of Commerce, Bureau of Census 1986).

Oil and gas is the largest segment of the industry, employing 600,000 workers, or about 60 percent of the mining workforce in 1982, followed by coal mining with 250,000 workers (23 percent), minerals materials with 110,000 workers (10 percent) and metallic minerals industries with 68,000 workers (8 percent). The minerals industry is largely made up of small companies with less than 20 workers. In 1982, just 14 percent of the 73,000 minerals establishments counted by the Bureau of the Census had more than 20 employees (U.S. Department of Commerce, Bureau of Census 1984).

Minerals production and processing are major components of the economies of many states. The importance of minerals to the economies of individual states are indicated by minerals production per capita (Table 1). Some states are especially significant minerals producers. Texas, Louisiana, Oklahoma, California, New Mexico, Wyoming, and West Virginia together contributed more than 75 percent of the $188 billion in value added by mining in 1982.

Table 1--Value of nonfuel and fossil fuel mineral production per capita by state, 1985

State	Population (thousands)	Value of non-fuel production $ (thousands)	per capita Dollars	Rank	Value of fossil fuel production $ (thousands)	per capita Dollars	Rank
Alabama	4,021	$405,915	101	20	1,618,678	403	16
Alaska	521	89,969	173	10	16,322,019	31328	1
Arizona	3187	1,550,085	486	3	246,766	77	26
Arkansas	2,359	256,697	109	18	854,107	362	17
California	26,365	2,094,796	79	24	11,866,004	450	15
Connecticut	3,174	72,386	23	47			
Colorado	3,231	408,178	126	16	1,679,821	520	13
Delaware	622	4,029	6	50			
Florida	11,366	1,559,266	137	14	301,681	27	29
Georgia	5,976	946,075	158	11			
Hawaii	1,054	53,272	51	37			
Idaho	1,005	348,154	346	6			
Illinois	11,535	459,920	40	39	2,224,616	193	19
Indiana	5,499	302,954	55	35	964,980	175	21
Iowa	2,884	228,017	79	25	14,893	5	33
Kansas	2,450	322,170	131	15	2,493,154	1018	11
Kentucky	3,726	267,558	72	27	4,199,363	1127	10
Louisiana	4,481	522,268	117	17	26,603,982	5937	3
Maine	1,164	41,108	35	42			
Maryland	4,392	258,274	59	32	75,245	17	31
Massachusetts	5,822	117,205	20	48			
Michigan	9,088	1,347,853	148	12	1,132,335	125	23
Minnesota	4,193	1,547,958	369	5			
Mississippi	2,613	102,793	39	40	1,334,864	511	14
Missouri	5,029	734,960	146	13	5,868	1	35
Montana	828	200,272	242	8	1,681,480	2036	8
Nebraska	1,606	99,970	62	31	173,110	108	24
Nevada	936	630,883	674	2	73,210	78	25
New Hampshire	998	32,900	33	44			
New Jersey	7,562	177,576	23	46			
New Mexico	1,450	656,889	453	4	4,821,283	3,325	4
New York	17,783	657,308	37	41	132,161	7	32
North Carolina	6,255	432,756	69	28			
North Dakota	685	24,184	35	43	2,040,042	2,978	5
Ohio	10,744	607,127	57	33	1,818,673	169	22
Oklahoma	3,301	251,607	76	26	8,793,517	2,664	6
Oregon	2,687	130,296	48	38	9,800	4	34
Pennsylvania	11,853	804,474	68	29	2,390,547	202	18
Rhode Island	968	12,192	13	49			
South Carolina	3,347	275,929	82	23			
South Dakota	708	207,339	293	7	44,878	63	27
Tennessee	4,762	472,287	99	21	218,195	46	28
Texas	16,370	1,733,359	106	19	36,654,454	2,239	7
Utah	1,645	312,359	190	9	1,597,920	971	12
Vermont	535	49,854	93	22			
Virginia	5,706	381,276	67	30	1,077,737	189	20
Washington	4,409	243,670	55	34	111,838	25	30
West Virginia	1,936	105,409	54	36	3,863,093	1,995	9
Wisconsin	4,775	125,110	26	45			
Wyoming	509	552,463	1,085	1	7,893,991	15,509	2
TOTAL	238,115	22,813,434	143		145,334,305	2,140	

Sources: U.S. Department of Energy 1987a-d;
U.S. Department of the Interior, Bureau of Mines 1987a.

Arizona's copper and Minnesota's iron ores together contributed about 33 percent of the value added by metallic minerals industries. Minerals produced in Colorado, Nevada, New Mexico, Wyoming, Missouri, and Idaho contributed, in that order, to another 33 percent of value added by metallic minerals industries. West Virginia and Kentucky together contributed some 40 percent of the total $18 billion value added by coal mining in 1982, with Pennsylvania, Illinois, Wyoming, Virginia, and Ohio accounting for another 40 percent.

Economically, the domestic minerals industry has been in decline since 1981 when combined production of all minerals peaked. However, the situation varies among sectors of the minerals industry. Bituminous coal production has increased significantly since 1973, while anthracite (hard coal) production has fallen over the past decade. Production of key metallic minerals -- iron ore, nonferrous ores, copper, lead and zinc -- all have fallen over the past 10 years, reflecting a decline in primary metals manufacturing (U.S. Bureau of the Census 1986).

Some Minerals Are of Strategic Importance

Energy minerals and some metallic minerals are of strategic importance because they are essential to the nation's security. U.S. military forces could not operate without fuel -- a fact recognized by President Taft in 1909 when he set aside oil reserves in California and Wyoming to assure fuel for the Navy (Wilkinson and Anderson 1985). Minerals also are key components of modern weapons systems. Tough, heat-resistant, and lightweight alloys are used in the engines of supersonic jet aircraft; chrome is used to line the barrels of cannon so they can withstand the force and heat of a high velocity projectile.

Laws Affecting Minerals Resources

The body of law affecting the development of federally-owned minerals is extensive and complex. The most important of the laws are the Mining Law of 1872, the Mineral Leasing Act of 1920, the Mineral Materials Act of 1947, the

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The Surface Resources Act of 1947, provided for the sale of sand, stone, gravel, and some other common materials used in construction or for decorative purposes.

The Surface Mining Control and Reclamation Act of 1977 provides federal incentives to states to control surface mining for coal and to reclaim abandoned mines. It also restricts or prohibits surface coal mining on National Forest System lands subject to valid existing rights and a determination as to whether mining is compatible with surface uses.

Other laws affecting exploration, development, and production of minerals and the reclamation of mined lands on forest and rangelands include the Geothermal Steam Act of 1970, and the Federal Land Policy and Management Act of 1976. Mineral development on both public and private land also is affected by environmental quality laws, particularly the National Environmental Policy Act, the Clean Water Act, Clean Air Act, and Toxic Substances Control Act (TSCA). States also have laws regulating minerals development that interact with the federal legislation.

Federal Agencies Responsible for Minerals Management

Primary responsibility for management of minerals rests with the Department of Interior, although other federal agencies play major roles in establishing policies and administering programs which affect minerals directly or indirectly. Within the Department of Interior responsibility for managing federally- owned minerals, data collection, planning, research, collecting fees, and managing minerals on federal lands is dispersed among five agencies.

The Bureau of Land Management (BLM) has overall management responsibility for fossil fuel and metallic minerals on federal federal minerals for the public domain it administers and for lands managed by other federal agencies. BLM also is responsible for minerals retained in federal ownership when surface ownership was transferred to private parties.

The Geological Survey (USGS) is responsible for collecting information on the extent of the nation's mineral resources. It inventories minerals deposits and their potential.

The Bureau of Mines (BOM) is responsible for collecting and analyzing scientific and technical information about the nation's minerals -- including supplies, consumption, and the minerals situation worldwide. It also conducts mining research and produces authoritative information on the nation's non-energy minerals in its annual Minerals Yearbooks and other publications.

The Office of Surface Mining, Reclamation and Enforcement (OSMRE) administers the Surface Mining Control and Reclamation Act of 1977, which covers surface mining for coal on both private and public land. Through provisions of the act, OSMRE oversees surface mine regulation by the states and administers a federal fund for reclamation of abandoned mines.

The Minerals Management Service is responsible for collecting revenues from leasing federal minerals both on-shore and on the outer continental shelf, and has primary responsibility for development of federal off-shore mineral resources.

The USDA Forest Service's minerals responsibility is limited to national forest land. Basically, the Forest Service is responsible for integrating use of underground resources -- minerals -- with use of surface resources. To do this it develops plans for surface and minerals use, reviews and approves proposals for minerals leases and permits, monitors performance of mine operators to ensure that environmental quality laws are met and that impacts to surface resources are minimized, and oversees reclamation. While BLM has primary responsibility for most minerals underlying National Forest System lands, The Forest Service is responsible for the sale of minerals materials such as rock, sand and gravel.

A number of other agencies, such as the Department of Energy, the Department of Commerce, and the Federal Emergency Management Agency play roles in establishing minerals policy.

States with significant minerals resources also have their own state agencies with responsibility for minerals management on state-owned and private lands.

Categories of Minerals and Indicator Minerals

For purposes of this analysis of the minerals situation in the United States, minerals have been placed in three broad categories:

* Energy minerals. These include the fossil fuels --- coal, oil and gas, and oil shale -- as well as other earth resources that can provide power, such as uranium and geothermal resources.

* Metallic minerals. These include metallic minerals such as iron, aluminum, chromium, cobalt, molybdenum, copper, lead, and precious metals such as gold and silver. Metallic minerals are essential to many consumer products and industrial processes, and are used in high-technology weapons systems.

* Industrial minerals. This is a broad category that includes minerals used in industrial processes, such as limestone and abrasives like industrial diamond and corundum; chemical minerals such as phosphate rock (used as a fertilizer) sulfur, and salt; common construction materials such as sand, gravel, clay, and stone; and gem stones like diamonds and emeralds. Major minerals categories and subcatagories are shown in Figure 1.

To simplify the analysis in this assessment of the nation's minerals situation, 13 minerals have been selected as "indicator minerals" for this report. These are minerals which have attributes and uses common to other minerals in its class, have common locational and market characteristics, and are found in significant amounts in the United States and on the national forests. The indicator minerals for each of the three categories are:

* Energy minerals -- oil, natural gas, coal, geothermal resources, and uranium;

* Metallic minerals -- copper, lead, molybdenum (a steel alloy), and the precious metals gold, and silver.

* Industrial minerals -- phosphate rock, limestone, and sand and gravel.

Figure-1 Categories of Mineral Resources

METALS

Metals Used in Iron Alloys

Iron Ore
Chrome
Cobalt
Columbium
Manganese
Molybdenum
Nickel
Tungsten
Vanadium

Base Metals

Antimony
Bismuth
Cadmium
Copper
Lead
Tin
Zinc

Light Metals

Aluminum
Magnesium
Titanium

Precious Metals

Gold
Platinum Group
Silver

Other Metals

Mercury

NONMETALLIC INDUSTRIAL MINERALS

Building Material

Cement
Gypsum
Limestone
Perlite
Sand & Gravel
Stone, Crushed
Stone, Dimension

Fertilizers

Guano
Limestone
Phosphate
Potash

Insulation

Asbestos
Mica
Vermiculite

Pigments and Fillers

Barite
Bentonite
Clays
Kaolin
Talc

Abrasives

Corundum
Flint
Garnet
Industrial Diamonds
Pumice

Gem Stones

Beryl
Diamond
Emerald
Opal
Sapphire

Ceramic Materials

Calcite, Optical
Clays
Feldspar
Fluorspar
Glass Sand
Quartz

Decorative Stones

Granite
Marble
Obsidian
Petrified Wood
Slate
Travertine

Chemicals (Diverse Uses)

Arsenic
Boron
Bromite
Carbon
Cesium
Chlorine
Fluorine
Graphite
Lithium
Salt
Silicon
Sodium
Sulfur

Water

Surface Water
Aquifers
Geothermal Sources
Hydropower Sources

Figure-1 Categories of Mineral Resources (Cont.)

METALS | **NONMETALLIC INDUSTRIAL MINERALS**

FOSSIL FUELS AND GASES

Coal
Natural Gas
Peat
Petroleum
Shale Oil
Synthetic Gas
ArgonCarbon Dioxide
Belium
Hydrogen
Neon
Nitrogen
Oxygen

Other

Amber
Fossil Plants, Animals

SOURCES: USDI Bureau of Mines. Mineral Community Summaries, 1979.

McDevitt, James F. and Gerald Manners. Minerals and Men, 2nd Edition. Baltimore: John Hopkins Press, 1974.

Following chapters examine trends in U.S. consumption of minerals; the nation's minerals resources; worldwide supplies; how domestic demand compares with supply; the economic, social and environmental implications of the supply-demand comparisons; opportunities for meeting the nation's requirements for minerals and constraints to these opportunities; and the implications for the Forest Service's resources programs.

I. TRENDS IN CONSUMPTION OF MINERALS AND PROJECTED DEMAND

HIGHLIGHTS

* The U.S. is among the world's leaders in minerals consumption.

* Demand for energy peaked in 1979, then decreased dramatically, but since 1983 energy use has increased at a moderate rate.

* Demand patterns for metallic minerals vary with the mineral, but there has been a general fall-off in demand since 1970, in part because some consumers have switched to cheaper, non-metal substitutes.

* Demand for energy minerals is expected to increase moderately, with a decrease in the use of oil and an increase in the use of coal.

* Demand for individual metallic minerals is volatile, but is expected to increase at a modest rate through 2040. High demand growth is expected for scarce and costly specialty metals, such as the platinum-group metals.

* Although the U.S. is a mineral-rich nation, it imports significant quantities of some minerals -- especially petroleum.

* The trend is toward increasing oil imports, although the U.S. has abundant supplies of coal which could substitute for foreign oil, and some experts say there are domestic supplies of oil which could be exploited if prices were favorable.

* For those metallic minerals of which the U.S. has reserves, future trends in imports will depend on the production costs of domestic minerals relative to the price of overseas supplies.

The United States is among the world's leaders in the consumption of many important minerals (Table I-1). With 5.8 percent of the world's population, Americans consume more than 30 percent of the world's annual production of natural gas, nearly 26 percent of the petroleum, 28 percent of the molybdenum, 27 percent of silver, and more than 21 percent of the lead and copper. However, other industrialized nations, notably Japan and West Germany, equal or surpass the U.S. in per capita consumption of some metallic minerals such as copper and crude steel. There will be increased demand for minerals in world markets as less developed nations industrialize.

Table I-1--U.S. consumption vs. world consumption, 1983

Commodity	Units	Domestic Consumption	World Consumption	US % of World Total
FUELS				
petroleum	million barrels/day	15.23	58.76	25.9
natural gas	billion cubic feet	16,835	54,388	30.9
coal (1)	trillion BTU's	15,900	79,796	19.9
NON-FUELS (2)				
Metals				
copper	thousand metric tons	2020	9,520	21.2
gold	thousand troy oz.	3,060	40,000	7.6
lead	thousand metric tons	1,141	5,240	21.7
molybdenum	million pounds	43	152	28.2
silver	million troy oz.	118.4	428.0	27.6
Materials				
limestone	thousand short tons	14,902	119,147	12.5
phosphate	thousand metric tons	34,830	135,000	25.8
sand, gravel	million short tons	619	8,100	7.6

1. Coal figures are given in British Thermal Units (BTUs) because the variation in energy content of a ton of coal varies world-wide. In the U.S. in 1983, 736.7 million short tons of coal were consumed.

2. Non-fuel mineral consumption is called "demand."

Sources: U.S. Department of Energy 1987a; U.S. Department of the Interior 1985.

National economic activity as reflected by gross national product, in addition to population growth, have some influence over minerals consumption and are expected to increase through 2040 (Figure I-1). However, increases in GNP and population do not necessarily mean a proportionate increase in minerals use. Since 1960 energy use per dollar of GNP has steadily declined, probably reflecting the mix of fuels -- coal, nuclear, gas, and oil -- used to generate electricity, combined with increased efficiency in generating equipment and manufacturing machinery (U.S. Department of Energy 1985). Likewise, per capita consumption of the traditional "tonnage metals" like copper, lead, and iron are

Figure 1-1--Index of demand for selected minerals, energy consumption, GNP and population, projections to 2040

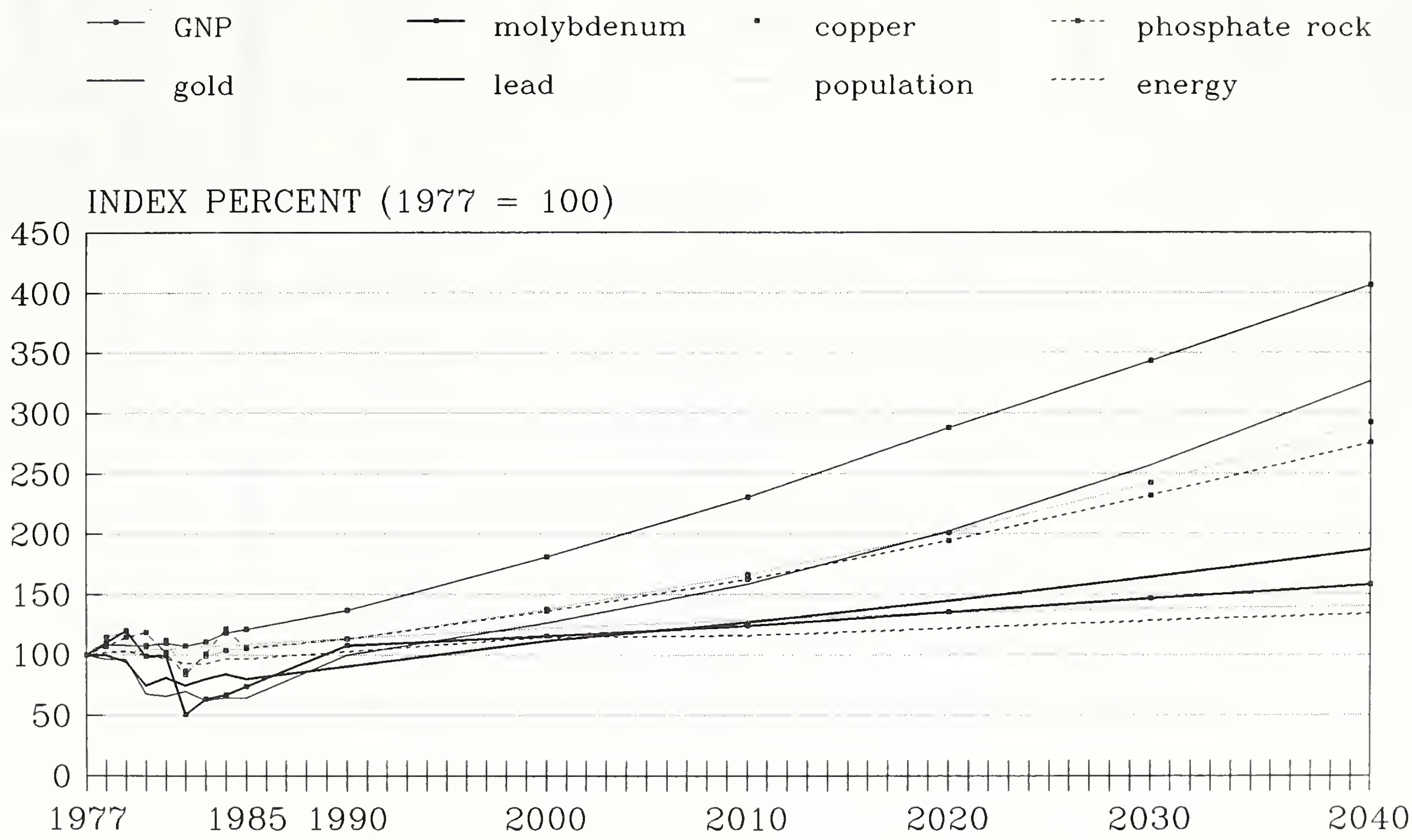


TABLE TO FIGURE I -1

Selected economic indicators and demand growth for certain minerals
selected years, 1955-1985, with projections to 2040

Year	Population (millions)	Gross National Product (billion 1987 $)	Total Energy Consumption (quadrillion BTUs)	Total Copper Demand (1000 metric tons)	Total Gold Demand (million troy oz.)	Total Lead Demand (1000 metric tons)	Total Molybdenum Demand (million lbs.)	Total Silver Demand (million troy oz.)	Total Lime Demand (million short tons)	Total Phosphate Rock Demand (million metric tons)	Total Sand and Gravel Demand (million short tons)
1955	165.9	1767.4	38.82	1637	1.3	1100	38.8	101.4	10.5	11.1	592
1965	194.3	2468.2	52.68	1982	5.3	1126	68.1	137	16.8	19.5	907
1975	216	3174.5	70.55	1473	4	1176	90	153.2	19.1	31.0	761
1977	220.2	3497.9	76.29	2035	5.3	1435	61.4	123.9	20.3	34.5	926
1978	222.6	3774.4	78.09	2333	5.1	1433	67.7	148.1	21	36.8	992
1979			78.9	2433	5.1	1358	73.7	130.6	21.5	39.6	945
1980	227.8	3768.1	75.96	2175	3.6	1070	60.6	91.2	19.4	40.8	762
1981	230.1	3841.1	73.99	2278	3.5	1167	61.1	168.6	19.3	35.1	689
1982	232.5	3743.2	70.84	1761	3.7	1075	31	150.1	14.4	28.8	593
1983	234.8	3872.3	70.5	2014	3.3	1148	39	174.8	15.1	34.8	653
1984	237	4128.6	74.06	2107	3.4	1207	41	169.1	16.1	41.8	772
1985	239.3	4224.9	73.96	2144	3.4	1148	45.4	160	15.9	36.4	798
↓ PROJECTIONS ↓											
1990	249.7	4780	78.6	2300	5.3	1300	66	140	19.2	39	750
2000	268	6331	87.3	2800	6.7	1600	71	150	27.5	47	1000
2010	283.2	8052	88.47	3379	8.4	1820	76	162	39.5	56	1330
2020	296.6	10071	93.15	4079	10.7	2072	83	175	56.8	67	1771
2030	304.8	12011	97.83	4923	13.6	2358	90	190	81.6	80	2357
2040	308.6	14214	102.51	5942	17.3	2683	97	206	117.4	95	3138

NOTE.--Non-fuel mineral projections are based on the average annual growth rate between 1983 and 2000, as calculated by the Bureau of Mines in the 1985 source listed below. See also Table 6.
1990 and 2000 energy consumption projections are by DOE, 2010-2040 are based on linear regression analysis performed by Floyd Deloney. R2=7.

Sources: U.S. Department of the Interior, Bureau of Mines 1981, 1984, 1985, 1987b.
U.S. Department of Energy 1987a.
U.S. Department of Agriculture, Forest Service 1986.

Index of economic indicators, and demand growth in energy and indicator non-fuel minerals, 1977-2040.

1977	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1978	101.1	107.9	102.4	114.6	96.2	99.9	110.3	119.5	103.4	106.7	107.1
1979			103.4	119.6	96.2	94.6	120.0	105.4	105.9	114.8	102.1
1980	103.5	107.7	99.6	106.9	67.9	74.6	98.7	73.6	95.6	118.3	82.3
1981	104.5	109.8	97.0	111.9	66.0	81.3	99.5	136.1	95.1	101.7	74.4
1982	105.6	107.0	92.9	86.5	69.8	74.9	50.5	121.1	70.9	83.5	64.0
1983	106.6	110.7	92.4	99.0	62.3	80.0	63.5	141.1	74.4	100.9	70.5
1984	107.6	118.0	97.1	103.5	64.2	84.1	66.8	136.5	79.3	121.2	83.4
1985	108.7	120.8	96.9	105.4	64.2	80.0	73.9	129.1	78.3	105.5	86.2
1990	113.4	136.7	103.0	113.0	100.0	90.6	107.5	113.0	94.6	113.0	81.0
2000	121.7	181.0	114.4	137.6	126.4	111.5	115.6	121.1	135.5	136.2	108.0
2010	128.6	230.2	116.0	166.0	158.5	126.8	123.8	130.8	194.6	162.3	143.6
2020	134.7	287.9	122.1	200.4	201.9	144.4	135.2	141.2	279.8	194.2	191.3
2030	138.4	343.4	128.2	241.9	256.6	164.3	146.6	153.3	402.0	231.9	254.5
2040	140.1	406.4	134.4	292.0	326.4	187.0	158.0	166.3	578.3	275.4	338.9

declining (Sousa 1987). Changes in the structure of the nation's economy, such as a continuation of the growth of the service and communications sectors and decline in energy-intensive manufacturing could moderate increases in the use both of energy and metallic minerals in the manufacture of durable consumer products and industrial machinery. However, significant growth in manufacturing and construction is expected even though those sectors are expected to decline in importance relative to other sectors of the economy (U.S. Department of Agriculture 1986a).

Technology also is a factor in minerals consumption, through development of new consumer products made with minerals, new processes permitting substitution of renewable materials, processes and products which use energy and minerals more efficiently, and processes which facilitate recovery and recycling. Thus, as technology reduces the amount of metallic minerals and materials required, it also generates new uses for minerals, thus expanding demand. There is a growing demand for specialty metals used as alloys or in the manufacture of composite materials (Sousa 1987).

Finally, demand also is affected in ways that are unpredictable by changes in social values, such as concerns over toxic materials.

In examining trends in minerals consumption, the price of minerals in a world minerals market cannot be ignored. World market prices affect the competitive position of the domestic minerals industry by influencing manufacturers' decisions about where they buy the minerals they use. Price also influences consumers' decisions about whether and what to buy, thus affecting overall

demand. How prices influence supply is discussed in greater detail in Chapter 3, The Minerals Supply Situation.

Past and Current Trends in Minerals Consumption

Energy Minerals

Following World War II, annual domestic consumption of all sources of energy, particularly fossil fuels, increased steadily until 1974, when the Organization of Petroleum Exporting Countries (OPEC) raised oil prices and limited production (Table I-2). After a significant drop in energy consumption in the mid-1970s, consumption turned upward and peaked in 1979 at just under 79 quadrillion British thermal units (quads). There was an abrupt decline in energy use to 70.5 quads in 1983, and since that time consumption has climbed moderately, to 73.9 quads in 1986 (Table I-3) (U.S. Department of Energy 1987b). Recent demand has been moderated by conservation measures and increased use efficiency in combination with the decline of energy-intensive heavy industry.

Table I-2--Trends in domestic fossil fuel consumption 1949-1985

Commodity	Unit	1949	1955	1965	1975	1985
petroleum	mil. barrels per day /quadrillion BTU	5.76 / 11.88	8.46 / 17.25	11.51 / 24.40	16.32 / 32.73	15.73 / 30.92
natural gas	trillion cubic feet /quadrillion BTU	4.97 / 5.15	8.69 / 9.00	15.28 / 15.77	19.54 / 19.95	17.28 / 17.85
coal	million short tons /quadrillion BTU	483.2 / 11.98	447.0 / 11.17	472.0 / 11.58	562.6 / 12.66	818.0 / 17.48
TOTAL	quadrillion BTU	30.46	38.82	52.68	70.55	73.96

Source: U.S. Department of Energy 1987a.

Table I-3--Consumption of energy by source, 1977-1986, with projections to 2000
(quadrillion BTU)

				-- history --						*		-- Projections (2) --				
Source	1977	1978	1979	1980	1981 `	1982	1983	1984	1985	1986	*	1987	1988	1989	1990	1995	2000
petroleum	37.12	37.97	37.12	34.2	31.93	30.23	30.05	31.05	30.92	31.89		32.2	31.7	31.7	31.8	32.6	34.7
natural gas	19.93	20.00	20.67	20.39	19.93	18.51	17.36	18.51	17.85	16.53		17.4	17.9	17.8	18.1	18.6	18.5
coal	13.92	13.77	15.04	15.42	15.91	15.32	15.90	17.07	17.48	17.32		17.8	18.5	18.7	19.1	21.7	23.6
nuclear	2.7	3.02	2.78	2.74	3.01	3.13	3.20	3.55	4.15	4.48		4.9	5.4	5.7	6.0	6.4	6.7
hydropower	2.51	3.14	3.14	3.12	3.11	3.56	3.87	3.72	3.36	3.50		(3)					
other	0.02	0.13	0.07	-0.03	-0.01	-0.02	-0.01	(1)	(1)	(1)		3.8	3.5	3.6	3.6	3.8	3.9
geothermal	0.08	0.06	0.08	0.11	0.12	0.10	0.13	0.16	0.20	0.22		(3)					
TOTAL	76.29	78.09	78.9	75.96	73.99	70.84	70.50	74.06	73.96	73.93		76.1	77.0	77.5	78.6	83.1	87.3

1. Less than 0.005 quadrillion Btu.
2. Projection figures are the Department of Energy's "base case forecasts."
3. Forecast figures for "other" sources of energy include geothermal and hydropower.

Sources: U.S. Department of Energy 1987a, 1987b.

Residential and commercial use accounted for the largest share of energy consumption in 1986 - 27.25 quads. Industry consumed 25.98 quads, and the transportation sector, 20.69 quads. Electric utilities, energy's middleman, consumed 26.79 quads (U.S. Department of Energy 1987b).

Between 1977 and 1986, each sector's share of total domestic energy consumption changed. The residential-commercial and transportation sectors registered increases (3.6 percent and 2.0 percent respectively), while the industrial sector's share fell a corresponding 5.6 percent. Electrical utilities consumed 6.5 percent more energy in 1986 than in 1977 (U.S. Department of Energy 1987b).

Since its inception in 1859, the modern petroleum industry grew at an exponential rate until the late 1970s, spurred in this century by the advent and ever-broadening use of automobiles. At the turn of the century, the U.S. used 60 million barrels of oil a year; in 1978, Americans consumed almost 7 billion barrels. In less than four generations, U.S. petroleum consumption multiplied more than 100 times, while population only tripled in size (U.S. Department of Energy 1987b; Resources for the Future 1960). Over the past decade, however, the U.S. has turned increasingly to its abundant coal reserves as a source of energy; between 1977 and 1985, consumption of both petroleum and natural gas declined, while consumption of coal increased 24 percent (Table I-3). From 1975 to 1985 the portion of the nation's energy provided by coal grew from 17.9 percent in 1975 to 23.6 percent in 1985. Meanwhile, oil's share of the nation's energy use fell from 46.4 percent to 41.8 percent and that of natural gas from 28.3 percent to 24.1 percent.

After sharp growth in the number of nuclear reactors and electricity generated in the early and mid-1970s, nuclear power generation fell late in the decade, hitting a low in 1980. Since 1980, the number of reactors on-line and the amount of power generated have increased (U.S. Department of Energy 1987c). Although nuclear power generation more than doubled between 1975 and 1985, it still provided only 4.15 quads of energy in 1985 (Table I-3), some 15.5 percent of all electrical power generated that year. Since 1974, orders for 117 nuclear power plants have been canceled, primarily because of high construction costs, reduced demand, and because it has been cheaper to generate electricity with coal (U.S. Department of Energy 1987c).

Geothermal resources used for electrical generation supply less than three-tenths of one percent of the nation's energy (10.3 million kilowatt hours in 1986), although geothermal power generation has increased 20-fold since 1970 (Table I-3).

Metallic Minerals and Precious Metals

Demand patterns in the metals industry vary from metal to metal. In general, consumption of metallic minerals rises and falls in consonance with domestic and worldwide economic prosperity and recessions, and periods of relative peace and military conflict. This is because metals contribute many of the primary materials for consumer products like cars and homes, and military weapons systems. The substitution of industrial minerals like carbon and glass, as well as plastics, in products traditionally made of metal has contributed to a general decline in demand since 1970. However, metallic minerals producers have become more cost-competitive in recent years, and traditional mineral

commodities like iron, lead, and copper are expected to maintain a steady share of the market and realize modest growth (Sousa 1987). Meanwhile, there is the prospect for high demand growth for high value specialty metals, such as the platinum-group minerals, for use in advanced metal alloys and tough, heat-resistant, and lightweight composite materials. One analyist says that "...all signs seem to point to a transition of some kind: from a largely undifferentiated commodity metals (and plastics) economy to one in which more highly specialized and technology-intensive materials play an increasingly important role" (Sousa 1987). While the use of precious metals in jewelry and industrial applications generate most of the demand for gold and silver, the psychology of individuals who buy the metals as a financial investment is an important factor. Recent trends in demand for the indicator minerals are shown in Table I-4 and are discussed below.

Table I -4--Trends in domestic non-fuel indicator mineral consumption, 1949-1985

Commodity	Unit	1949	1955	1965	1975	1985
METALS						
copper (1)	thousand metric tons	1056	1637	1982	1473	2144
gold (2)	million troy oz.	3.1 (3)	1.3	5.3	4.0	3.0
lead (2)	thousand metric tons	868.8	1,100.1	1,126.3	1,176.7	1,148.3
molybdenum (2)	million pounds	21.3 (3)	38.8	68.1	90.0	33.5
silver (2)	million troy oz.	97.7	101.4	137.0	153.2	118.6
MATERIALS						
lime	million short tons	6.3	10.5	16.8	19.1	15.7
phosphate (1)	million metric tons	7.7	11.1	19.5	31.0	36.4
sand and gravel	million short tons	319	592	907	761	799

1. apparent consumption
2. reported consumption
3. average 1946-1950

Sources: U.S. Department of the Interior 1951, 1957, 1967, 1977, 1987a; U.S. Bureau of Mines commodity specialists 1987.

Copper--Between 1972 and 1982, copper consumption declined along with onstruction, one of its major markets. The boom of the mid-eighties caused a drastic reduction in inventories, and the price for copper rose dramatically. The automobile, housing and appliance market all expanded and the demand for copper rose to record levels. However, cheaper substitutes have made significant inroads into traditional copper markets. Aluminum, because it is lighter, has challenged copper's dominance in overhead transmission lines, while drainage pipes, once a major use of copper, now are predominantly made of plastic (Edelstein 1987).

Lead--The demand for lead has declined since the early seventies and will probably continue to fall as its use in gasoline and paints is phased out. Between 1973 and 1983, the use of lead as a gasoline additive plummeted by 65 percent. In 1983, lead's use in automobile batteries accounted for 70 percent of total domestic consumption (U.S. Department of Interior, Bureau of Mines 1985). There has been an increasing demand for lead to shield radiation from television sets and computer video display terminals (Latimer 1987), although the overall health of the industry still depends on demand for auto batteries. Recycled lead accounts for about 50 percent of annual domestic consumption -- the highest recycling rate for any metal except antimony (U.S. Department of the Interior, Bureau of Mines 1987b).

Molybdenum--Molybdenum is used primarily as an alloying agent in steel and cast iron to enhance hardness, strength and corrosion resistance. Its versatility guarantees a continued demand for the metal, but levels of domestic consumption depend to a great extent on the steel industry, its major market. Since the

early 1960s, molybdenum has experienced a domestic annual demand increase of just under one percent, but with many peaks and valleys (U.S. Department of Interior, Bureau of Mines 1985). Demand for molybdenum -- both domestically and worldwide -- hit its high point in 1979 and sank to an all-time low in 1982. Recently, molybdenum has been threatened by a cheaper alloy substitute and an increasing trend toward the use of plastics instead of steel (Blossom 1987).

The U.S. is the major world supplier of molybdenum, exporting more than 50 percent of domestic production. Because of the desirability of selling the metal overseas to help the nation's balance of payments, overseas demand must be considered a complement to domestic demand. Although exports have been declining for the past decade, the U.S. exported more than 55 million tons of molybdenum in 1986 (U.S. Department of the Interior, Bureau of Mines 1987b).

Gold--Jewelry has always been the most important end use for gold, although industrial uses burgeoned as the electronics industry grew in the fifties and sixties. Since 1975, jewelry has accounted for over half of all domestic gold consumption, despite high prices in 1980-83. Industrial applications, mostly in electronics, account for 32 percent of demand. During the last 20 years, dentistry has accounted for 10 to 15 percent of demand. Since legalization of private ownership in 1975, consumption of gold in coins, medallions, and other items purchased as investments has amounted to as high as six percent of annual demand. However, investment demand has fluctuated wildly, ranging from a high of 268,000 troy ounces in 1977 to a low of 4,000 troy ounces in 1983, testament to the unpredictability of investor psychology.

__Silver__--Domestic consumption peaked in 1973 at 197 million ounces and has since declined, amounting to 128 million ounces in 1985. (U.S. Department of the Interior, Bureau of Mines 1985). Silver also is used for jewelry (almost 7 percent in 1983), but since 1967, photographic materials have constituted the largest domestic industrial use, followed by the electrical and electronics industry (U.S. Department of the Interior, Bureau of Mines 1985).

Industrial Minerals

__Limestone__--Limestone is used primarily for chemical and industrial purposes, in steel furnaces and in reducing particulate emissions from industrial smokestacks, among other uses. Demand and production were steady in the seventies, but in the early 1980s demand experienced a massive drop, to 75 percent of the consumption level the decade before. Decrease in use of limestone reflects a decline in steel production.

__Phosphate Rock__--The fertilizer industry is the major consumer of phosphate. The domestic fertilizer industry is considered to be mature; little growth is expected given consolidation and some reduction in the agriculture industry. Over the past 10-15 years domestic demand has declined and production facilities have been shut down or consolidated. However, two thirds of annual phosphate rock production is exported, and foreign markets are strong.

__Sand and Gravel__--From the end of World war II until the mid-1960s, demand for sand and gravel steadily increased at a rate of about eight percent annually. Then growth slowed and in the early 1980s demand began to decline. In 1982,

demand for sand and gravel was about the same as 1955 --- just over 590 million short tons (Table I-4). The drop in demand for sand and gravel reflects the fortunes of the construction industry which during the 1970s and the early 1980s was battered by inflation, high interest rates, effects of the OPEC oil embargo and general economic recession. The U.S. exports a small amount of sand and gravel (U.S. Department of the Interior, Bureau of Mines 1985, 1987b).

Projected Trends in U.S. Demand for Minerals

Energy Minerals

The Annual Energy Outlook published by the Department of Energy's Energy Information Administration projects energy demand only to the year 2000. Its base case consumption forecasts for selected years through 2000 by are shown in Table I-5.

Table I-5--Summary of projected base case energy consumption (Quadrillion Btu per year)

	1987	1988	1989	1990	1995	2000	% 1987 2000
Petroleum	32.6	33.0	33.4	33.7	35.1	36.3	.8
Natural Gas	17.4	17.4	17.8	17.8	18.9	20.2	1.2
Coal	18.0	18.0	18.3	18.8	20.8	22.6	1.8
Nuclear	4.9	5.3	5.5	5.9	6.3	6.4	2.1
Hydropower/ Other1	3.3	3.5	3.7	3.8	3.9	4.1	1.6
Total	76.2	77.2	78.8	79.9	85.0	89.6	1.3

Source: Department of Energy, Energy Information Administration, 1988. Annual Energy Outlook 1987 with Projections to 2000

1 Includes industrial generation of hydroelectric power, net electricity imports, and electricity produced from geothermal, wood, waste, wind, photovoltaic, and solar thermal sources connected to electric utility

In order to project energy demand to the year 2040 as required for this Assessment, an energy supply-demand model developed by Jae Edmunds and John Reilly (1986), Institute for Energy Analysis, Oak Ridge Associated Universities, was used. The Edmunds-Reilly model was developed for the Department of Energy to project the long-term production of atmospheric carbon dioxide from consumption of energy world-wide. Basically, the model projects consumption of energy from oil, gas, solids (encompassing coal and biomass), and nuclear energy at decade intervals through the year 2050. Since the model's benchmark year differed from those of this Assessment, a trend line was developed and used to establish projected demand levels for the Assessment's benchmark years. The projected demand for the four categories of energy, in both Btus and units by which each commodity is traditionally measured, is shown in Table I-6.

Table 1.6--Projections for Energy Demand through 2040

commodity	units	1987	1991	1995	2000	2005	2040
coal	quadrillion Btu	22.99	25.96	29.19	33.22	29.93	37.67
	billion short tons	1.04	1.18	1.33	1.51	1.36	1.71
oil	quadrillion Btu	27.56	28.63	29.69	31.01	31.94	36.28
	billion barrels	4.75	4.93	5.11	5.34	5.50	6.25
gas	quadrillion Btu	16.83	15.74	14.65	13.29	15.25	25.81
	trillion cubic feet	16.29	15.23	14.18	12.86	14.76	24.98
nuclear	quadrillion Btu	4.67	5.55	6.43	7.53	8.47	14.51
	billion kilowatt hours	432.04	513.46	594.87	696.64	783.60	1342.39

Note.--The figures in quads were derived from the Edmunds model. To calculate demand in the units by which each commodity is traditionally measured, Department of Energy's thermal conversion rates were used. For coal, the average heat content of all coal in 1986 was 21.932 million Btu/short ton. Edmunds' projections are for biomass solids, a major part of which are coal. We subtracted 10 percent of the projected biomass demand to calculate coal demand after the year 2000. For oil, the thermal conversion factor used was 5.800 million Btu/barrel. For gas, the heat content calculated was 1,033 Btu/cubic foot. For nuclear power plant generation, DOE used the weighted annual average heat rate for nuclear steam-electric plants in the U.S., which was 10,809 Btu/kilowatt hour in 1986.

Sources: U.S. Department of Energy, Energy Information Administration. 1987. Annual energy review 1986. p. 262, 264-267, 271-276.

Edmunds, J., and Reilly, J. 1986. The IEA/ORAU long-term global energy-CO2 model: personal computer version A484PC. Washington: Oak Ridge Associated Universities. 281 p.

The price of energy, discussed in detail in the following chapter on minerals supplies, will have a major influence on demand, and the sources Americans tap for their energy. Rising oil prices could stimulate a shift to use of domestic coal and biomass-based fuels, including wood. Moreover, increased prices for oil could make production of synthetic fuels, such as gas from coal and gasoline substitutes from corn and other vegetable substances, and the use of alternative energy sources -- such as solar and wind -- economically viable.

Some authorities believe the nation is in a period of transition from reliance on fossil fuels -- especially petroleum and natural gas -- to substantial use of renewable energy sometime in the next century. Under this scenario, rising prices and uncertain supplies of petroleum will lead to increased use of coal and a concentrated effort to develop renewable energy technologies (Backus 1981).

Metallic Minerals and Precious Metals

Projecting long-term demand for any specific metallic mineral is difficult because domestic demand is influenced by many factors, some relating to economic and social developments in the United States, others to world economic, political, and military events which influence levels of supply and consumer prices.

As with energy minerals, demand for metallic minerals has been linked to population growth, gross national product, and disposable incomes. The vigor of the domestic durable goods manufacturing sector, communications, and defense industries all have a bearing on the domestic demand for metallic minerals.

The demand for gold and silver largely is influenced by the world price of these precious metals.

The Bureau of Mines has projected consumption of some important minerals to the year 2000, based on analysis of trends in GNP, gross private domestic investment (GPDI), Federal Reserve Board production indices, and population growth. For purposes of this assessment, the Bureau of Mines' projections of average annual probable demand through 2000 for the indicator minerals were extended to 2040 (Table I-7, Figure I-1). These projections provide a picture of what future demand might be <u>if present trends continue</u>. For example, the Bureau of Mines projects the demand for copper to grow at an average annual rate of 1.9 percent through 2000; projecting this to 2000, the domestic demand for copper would increase from the 2.1 million metric consumed in 1985 to 5.9 million metric tons in 2040. Similarly, at a 2.4 average annual growth rate, domestic consumption of gold would increase from 3.4 million troy ounces in 1985 to 17.3 million troy ounces in 2040. However, it is impossible to anticipate technologies that may have a profound influence on consumption of individual minerals. Some of the factors expected to affect future demand are discussed below. Except where otherwise noted, the discussion is drawn from <u>Minerals Facts and Problems, 1985 edition</u> (U.S. Department of Interior, Bureau of Mines 1985).

<u>Copper</u>--Because of its use in construction, manufacturing and communications, copper's fortunes depend to a large degree on the health of the nation's economy. Modest growth amounting to 1.9 percent annually is projected through 2000. Copper will face increased competition from substitutes in some markets,

Table I-7--U.S. total demand projections to the year 2000

Commodity	Units	Low	High	Probable	Average annual growth rate - 1983 -2000
METALS					
Copper	1000 mton	2400	3500	2800	1.9
Gold	1000 oz.	5000	8300	6700	2.4
Lead	1000 mton	1100	2200	1600	1.3
Molybdenum	mil. lbs.	60	100	71	0.8
Silver	mil. oz.	120	180	150	0.8
MATERIALS					
Lime	1000 ston	21900	35200	27500	3.7
Phosphate	1000 mton	45000	50000	47000	1.8
Sand and Gravel	mil. ston	650	1230	1000	2.9

Source: U.S. Department of the Interior, Bureau of Mines 1985.

but new uses in electronics and communications, and the recapture of some older markets in construction and transportation are projected to more than offset losses. Nearly 60 percent of the forecast for probable total end-use demand for copper in the year 2000 is in electrical products. Growth in this sector, copper's most important market, closely matches projections of gross private domestic investment. Copper's use by the electrical and electronics industry is not expected to decline further before 2000, and use by the construction sector is expected to increase somewhat as copper roofing and other uses are revived. A significant portion of domestic demand for copper has been met by the recovery of old scrap, which has averaged 35 percent of total domestic demand for more than half a century. This proportion is not expected to grow much before 2000. Scrap recovery diminishes during periods of low prices, and the international availability of inexpensive primary copper discourages recycling.

Lead--Trends in demand for lead are strongly linked to growth of the auto industry; 75 percent of lead production is used in automobile batteries. Past demand for lead has matched growth in GNP, and projections for a moderate, but steady, growth in demand averaging 1.3 percent annually through the year 2000 is linked to projected growth in GNP. Increased use of lead by the electronics industry, and recapture of the lead cable sheathing market should further contribute to a rising demand for lead.

Molybdenum--Some 75 percent of molybdenum production is used as a steel alloy, and the fortunes of the steel industry, both domestically and in other countries, largely will determine demand for molybdenum. Prevailing demand patterns plus some growth in demand for specialty steels containing molybdenum alloy are expected to continue through the end of the century, contributing to a modest but stable overall demand growth of just under one percent a year through 2000. Since the majority of domestic production of molybdenum is exported (62 percent in 1986), overseas industrial development will play a significant role in global demand for molybdenum (U.S. Department of Interior, Bureau of Mines 1987b).

Gold--The demand for gold is projected to grow at an average annual rate of 2.4 percent until 2000. Gold demand is strongly influenced by the world price of the metal. Demand for gold in the form of jewelry and luxury items -- more than half of gold's market -- responds to the metal's world price, rather than changes in GNP or population. Demand for gold in dentistry, expected to comprise about 10 percent of gold's market in the year 2000, will be influenced by the development of substitutes, improved oral hygiene and the possible

advent of government programs which would expand access to dental care. Projected growth in the electronics component industry - gold's other major market - depends on trends in equipment longevity, substitution, and discovery of new industrial applications. Increased demand for gold investment products is expected to be minimal.

Silver--Only moderate growth in the demand for silver -- eight-tenths of one percent as an annual average -- is anticipated over the next decade as industries that use silver in manufacturing consume less silver per product unit and as substitutes increase their market share. Improved recovery methods for used silver are expected to further dampen demand for newly-mined metal. The trend towards substitutes and increased use-efficiency is expected to affect foreign markets as well as domestic ones, although larger demand growth is projected for the rest of the world than for the U.S.

Industrial Minerals

Limestone--The chemical and industrial sector is the biggest user of lime, the commodity produced from limestone. In 1983, the chemical and industrial sector used ten times the amount of lime as the construction industry, limestone's second biggest market. By 2000, the amount of limestone used for chemical and industrial purposes is projected to nearly double 1983 consumption levels -- to 24.6 thousand short tons or nearly 90 percent of domestic consumption. These estimates are based on a projected 1.8 percent growth in the iron and steel industry, and an expected increase in demand for lime in the environmental sector -- for use in cleaning smoke-stacks and in sewage treatment and land reclamation. Demand for lime in agriculture is expected to remain flat. The

projected 3.7 percent annual average growth in the demand for limetone is based almost exclusively on expected growth in the chemical and industrial sectors.

<u>Phosphate Rock</u>--Projections for increased demand for phosphate rock in the year 2000 are based primarily on the expectation that there will be significant growth in the export fertilizer market, and moderate growth in the domestic fertilizer market. The Bureau of Mines projects probable average annual growth in these two markets through the year 2000 at 2.7 percent and 1.3 respectively. Despite the strength of these markets, the U.S. share of world phosphate sales probably will decline because large foreign reserves are expected to be developed by 2000.

<u>Sand and Gravel</u>--Current trends and end-use shares are expected to continue. Between 1974 and 1983, 45 percent of all sand and gravel was used for concrete aggregates and concrete products. Increased use of crushed stone as a substitute for sand and gravel in concrete, asphalt, and road-base uses is expected to significantly affect demand for sand and gravel. An important factor in substitution decisions are the distances over which sand and gravel must be hauled. Delivery costs increase the end-user prices and encourage the search for substitutes like crushed stone.

Trends in the Imports of Minerals

Though the U.S. is a mineral-rich nation, The U.S. imports significant quantities of some minerals. Oil is imported to supplement domestic supplies. Some minerals are imported even though there are active mines in the U.S. because it is cheaper to buy overseas than to develop and produce domestic

supplies. Other metallic minerals are imported because the minerals do not occur in the U.S. in sufficient quantities or domestic reserves are uneconomic given current prices and technology.

On the other hand, the U.S. also exports significant amounts of some minerals. The U.S. is the world's major supplier of molybdenum, exporting 55 million pounds of the 88 million pounds produced in 1986 (U.S. Department of Interior, Bureau of Mines 1987b). Nearly 10 percent of domestic production of limestone rock (nine million tons of the 40 million tons produced) was exported in 1986. The U.S. also exports significant amounts of some minerals that it also imports in large quantity. For example, in 1986, the U.S. imported 21 million tons of iron ore, produced 40.7 million tons, and exported 4.2 million tons. In 1985, the U.S. exported $13 billion worth of non-fuel minerals. The U.S. also is a major international supplier of coal, marketing $3.9 billion dollars overseas in 1986 (U.S. Department of Energy 1987a). Though it imports more than half of the petroleum consumed domestically, the U.S. sold petroleum products worth $3.5 billion overseas in 1986.

Trends in Energy Minerals Imports

The nation's oil imports rose steadily from 1960 to 1977 when imports accounted for nearly one in every two barrels of oil (46 percent) consumed in the U.S. (about 8.6 million barrels a day). U.S. reliance on foreign oil fell to 27.3 percent of consumption (4.3 mbd) in 1985, then increased to 32.8 percent (5.3 mbd) in 1986 (Table I-8a). The National Energy Plan projects foreign oil to account for 16 percent of U.S. consumption (8.3 mbd) in 2010. Other observers expect far heavier U.S. reliance on foreign oil, perhaps exceeding 50 percent

Table I-8a--Net fossil fuel imports as a percent of consumption, 1960-1986

Commodity	1960	1965	1970	1975	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Crude oil	16.5	19.8	21.5	35.8	46.5	42.5	43.1	37.3	33.6	28.1	28.3	30.0	27.3	32.8
Natural Gas	1.2	2.8	3.6	4.5	4.9	4.6	5.9	4.7	4.4	4.9	5.1	4.4	2.5	4.4

Source: U.S. Department of Energy 1987b.

of domestic consumption by 1991 if present trends in U.S. consumption and production persist (U.S. Department of Energy 1987e; Abelson 1987). However, the U.S. has abundant supplies of coal, oil shale, and natural gas which could replace imported oil in some cases, depending on technology and the economics of production. There is some evidence that significant supplies of on-shore oil remain which could be exploited with new technology (Fisher 1987).

Trends in Imports of Metallic Minerals

Imports of metallic minerals and precious metals have fluctuated considerably over the past decade. The percentage of indicator minerals imported is shown in Table I-8b. The United States has consistently imported substantial amounts of copper, lead, gold and silver. The U.S. is the world's largest supplier of molybdenum.

For those metallic minerals and precious metals of which the U.S. has ample supplies, future trends in imports of these minerals will depend in large measure on the cost of domestic minerals relative to the cost of overseas supplies, and on world political and economic factors. Moreover, the strength or weakness of the domestic economy relative to other developed nations could lead to policies and programs intended to bolster domestic production and manufacturing. Such a scenario could promote the development and exploitation of domestic mineral reserves. Continued low valuation of the dollar relative

Table I8-b--Total net imports of indicator non-fuel minerals as a percent of consumption, 1977-1986

Commodity	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
METALS										
Copper	13	20	13	16	6	1	19	23	28	27
Gold	61	53	53	18	15	42	30	37	46	21
Lead	13	9	5	NE	1	11	20	20	13	20
Molybdenum	NE	NE	NE	NE	NE	NE	7*	NE	NE	NE
Silver	31	48	42	7	53	55	61	59	60	69
MATERIALS										
Lime	2	3	3	2	2	2	2	1	1	1
Phosphate Rock	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Sand and Gravel	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE

* "Unusually large decreases in domestic stocks resulted in a positive net import reliance as a percent of consumption." (U.S. Department of the Interior, Bureau of Mines 1987b, p. 106)

NOTE.--"NE" denotes net exporter.

Source: U.S. Department of the Interior, Bureau of Mines 1981, 1984, 1987b.

to the currencies of other countries also could make domestic minerals more cost-competitive with foreign minerals, thus decreasing the use of imported minerals. Threats to foreign supplies, through armed conflict or political instability in critical source countries, and U.S. policy decisions aimed at maintaining minerals independence also could reduce imports.

Trends in Imports of Minerals Materials

The United States does not import significant amounts of minerals materials and is a net exporter of phosphate rock and sand and gravel.

CHAPTER II. THE NATION'S MINERALS RESOURCES

HIGHLIGHTS

* The nation is rich in many of the minerals it requires, but there is great uncertainty about the extent of the nation's minerals resources.

* While minerals are widely distributed around the nation, coal is concentrated in the Allegheny Plateau, the Ohio River Valley, and the Great Plains; oil is found mostly in the Southwest and South; metallic minerals occur predominantly in the upper Lake States and the Rocky Mountains.

* Ownership of the nation's minerals is complex; there is little information on quantities of minerals in public and private ownership.

* The quantity of recoverable oil is uncertain over the long-term, but the nation has abundant coal reserves, oil shale and tar sands, uranium, and the potential for greater use of geothermal resources.

* The U.S. possesses large quantities of many metallic minerals, although they may not be economic to develop at current prices or with available technology.

* Nationwide, there is large quantities of minerals materials used in construction, though urban development threatens their availability in some areas.

Because minerals are contained in soil and rock, some at great depths, the extent of the nation's minerals resources will never be known. While minerals are non-renewable and thus finite, the resource itself is expandable through investment in exploration and development, and the development of new techniques for minerals discovery and recovery.

In reality, relatively little is known about the extent of the nation's minerals resources (Cameron 1986). Nonetheless, the United States is rich in many of the minerals it requires. In 1986 it was among the top three producing nations worldwide of some 33 of the 87 minerals monitored by the Bureau of Mines and a major producer of several others (Figure II-1). For many mineral

Figure II-1--Minerals of which the United States is among the top three world producers.

Aluminum	quartz crystal barite
barite	rare earth metals
beryllium	rhenium
boron	salt
bromine	silicon
cadmium	sodium carbonate
cement	sulfur
copper	talc and prophyllite
diatomite	titanium
feldspar	vermiculite
industrial garnet	
germanium	
gypsum	
helium	
lime	
magnesium	
mercury	
mica	
molybdenum	
ammonia	
perlite	
phosphate	

Source: U.S. Department of Interior, Bureau of Mines 1987b.

commodities, even for some of those that are imported, the U.S. has significant known reserves. For example, the domestic reserve base of copper, which the United States imports in significant quantities, is sufficient to last 40 years at 1986 consumption rates (Table II-1). However, there are no economic domestic supplies of some metallic minerals of economic and military importance.

There is disagreement over quantities of recoverable on-shore oil in the contiguous U.S. However, the U.S. has abundant supplies of coal, oil shale, and tar sands, and uranium for nuclear power, and potential for development of additional geothermal resources. The amount of oil in recoverable domestic reserves as estimated by the Department of Energy would last 9 years at mid-1980s production rates. This recoverable reserve base estimate in terms of

Table II-1--Domestic and world supply, demand and reserve base for non-fuel minerals, 1985

Mineral	Units	US Mine Production	US Consumption (1)	Reserve Base (2)	Years to exhaust reserves (3)	World Mine Production	World Reserve Base	Domestic % of World Reserve Base
METALS								
Copper	1000 mtons	1,106	1,906	90,000	47	8,114	556,000	16
Gold	mil. oz.	2.48	3.10	120	39	48.22	1,490	8
Lead	1000 mton	424	1,113	26,000	23	3,390	142,000	18
Molybdenum	1000 lb.	108,409	33,451	11,800,000	353	215,139	26,000,000	45
Silver	mil. oz.	39.4	128	1,800	14	412.3	10,800	7
MINERAL MATERIALS								
Limestone	1000 ston	15,713	15,865	adequate		125,531	adequate	
Phosphate	1000 mton	50,835	36,384	5,200,000	143	151,863	36,000,000	14
Sand and Gravel	1000 ston	829,530	798,800	(4)		not. avail.	(4)	

1. Usually both reported and apparent consumption figures are given for each commodity. Reported consumption, usually the lesser figure, was chosen for this table since apparent consumption usually includes recycled material.
2. The "reserve base" constitutes that part of identified resourced which may reasonably become economic to exploit, without assuming current technological or economic standards.
3. The number of years it will take to exhaust the reserve base at 1985 consumption rates as indicated above.
4. "The reserve base is controlled largely by land use and/or environmental constraints. Local shortages of sand or gravel are common." (p. 137, BOM, 1987)

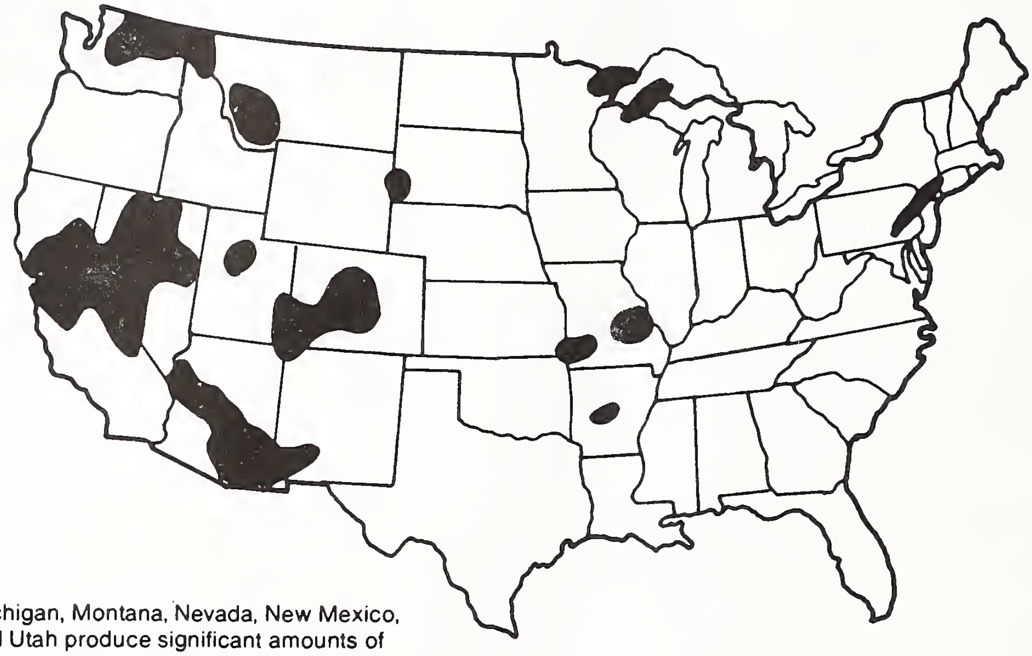
Source: U.S. Department of the Interior, Bureau of Mines 1987b.

years of supply is about the same for natural gas. Domestic coal reserves are considerably more extensive--these reserves would last over 500 years at current production rates.

Where Minerals Are Located

Generally speaking, the areas of highest mineralization are the mountains and basins of the West and the Appalachian chain in the East (Figure II-2). However, minerals of economic importance are widely scattered throughout the United States. For example, there are identified iron deposits in all but six states. Moreover, ores predominantly of one mineral often contain another mineral which can be economically produced as a byproduct or co-product. For example, cadmium often is a byproduct of zinc and cobalt is a byproduct of copper and nickel.

Figure II-2
Map of Mineralization
Locations of Favorable to Metallic Ore Deposits



Michigan, Montana, Nevada, New Mexico, and Utah produce significant amounts of copper, and the bulk of U.S. production comes from Arizona and Utah (National Research Council 1979).

☐ Mineralized
■ Heavily mineralized
☐ Federal lands

Key
1. Cobalt
2. Zinc
3. Cobalt-nickel
4. Platinum

Coal underlies about 13 percent of the nation and occurs in 37 states (U.S. Department of Agriculture, Forest Service 1979) although the bulk of the nation's coal reserves are located beneath the Allegheny Plateau and Cumberland Plateau in the East, the Ohio and Mississippi River Valleys and the Great Plains (Figure II-3). Oil deposits are concentrated in an area extending from Oklahoma south to central Texas, with scattered deposits beneath the Eastern plateaus and in Western basins (Figure II-4). Geothermal resources occur mainly in the West (Honig, Olson, and Mason 1981).

Figure II-3--Map of Coal Areas

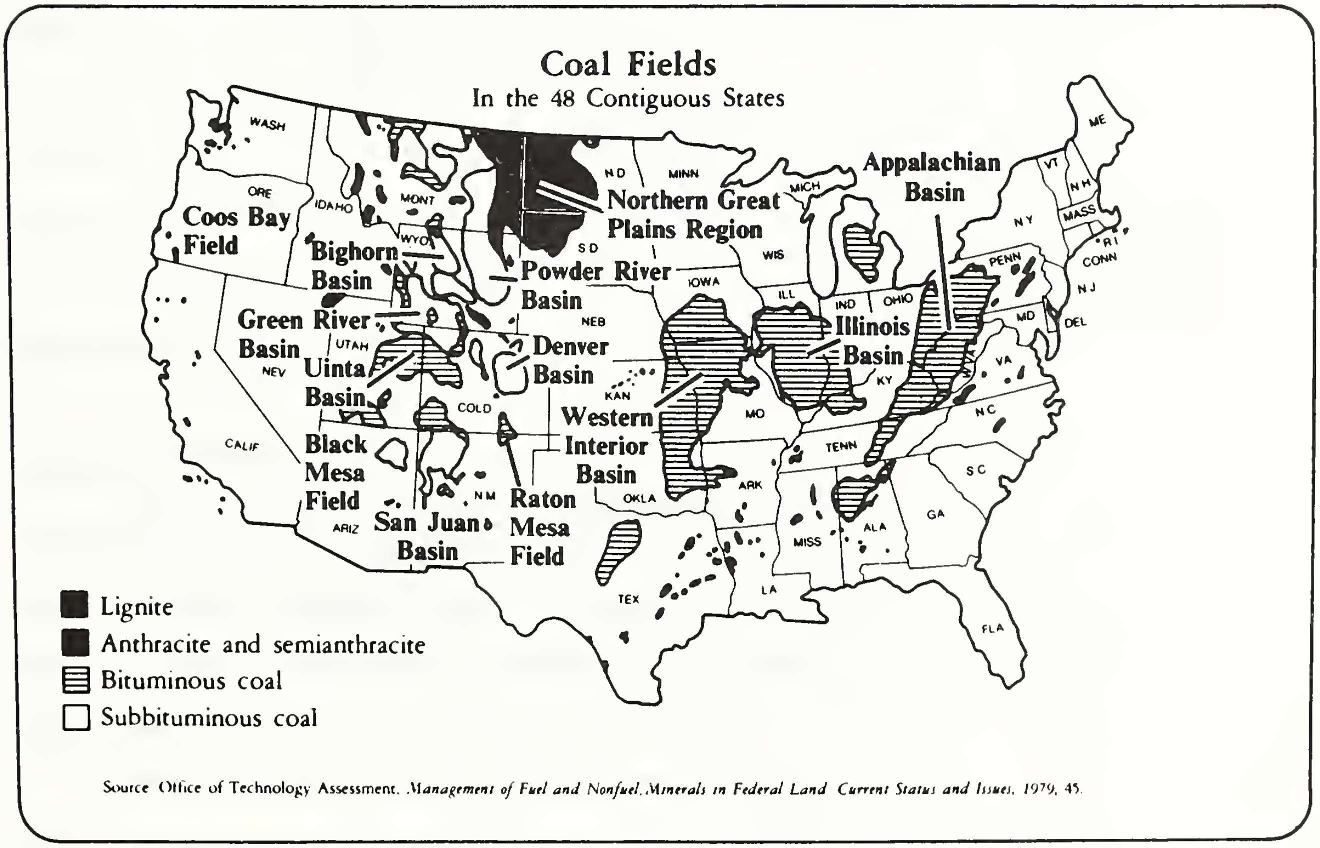
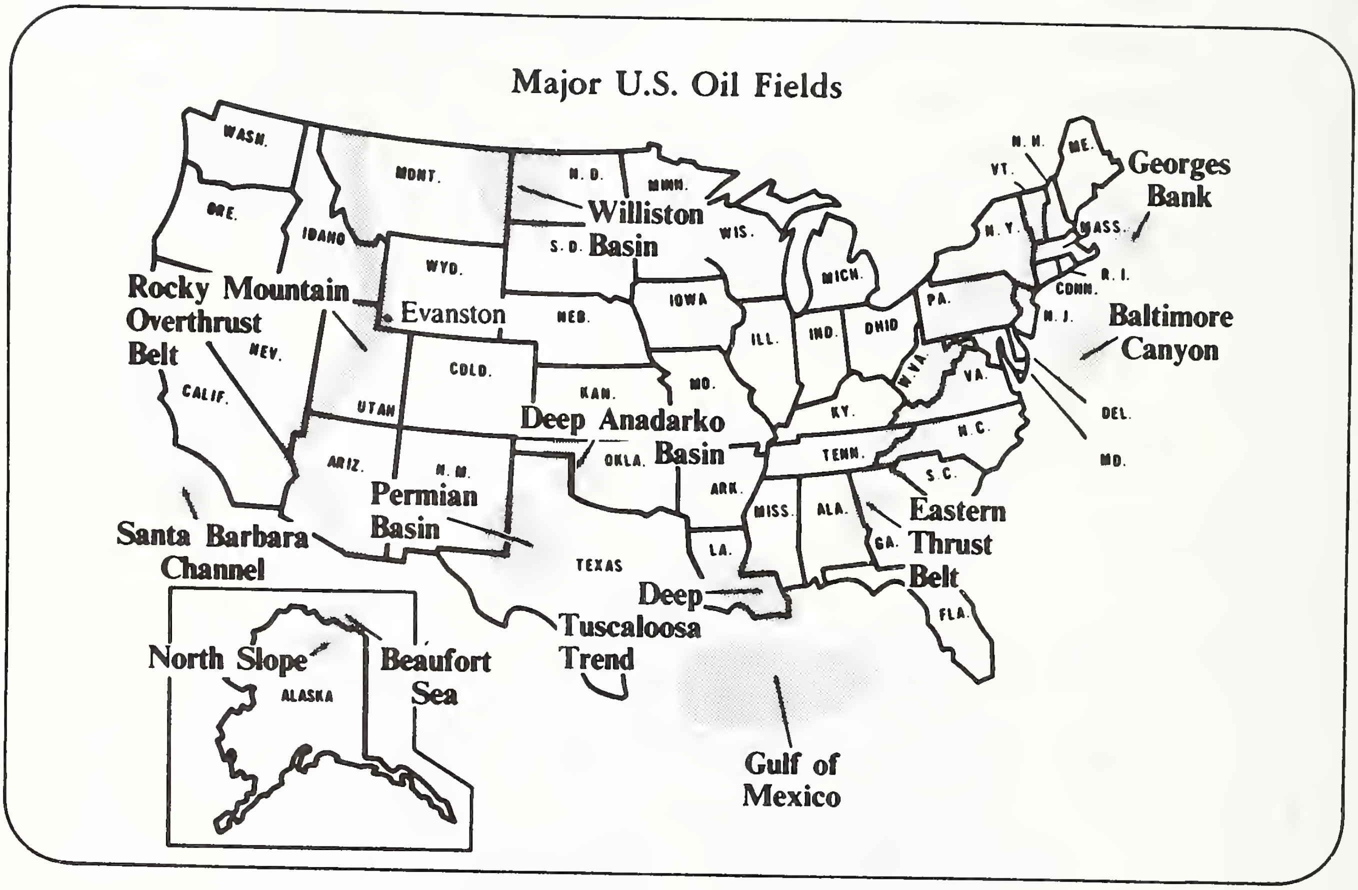


Figure II-4--Map Showing Domestic Oil Resources



Although deposits of given mineral commodity may be found in many areas of the nation, production typically is far more limited (Honig, Olson, and Mason, 1981; Bureau of Mines 1987b). For example, although there are deposits of copper throughout the Appalachian Mountains, Missouri, Oklahoma, Michigan, Minnesota and all the Western contiguous states, only six states (Arizona, Michigan, Montana, Nevada, New Mexico, and Utah) produce significant amounts of copper, and the bulk of U.S. production comes from Arizona and Utah (National Research Council 1979).

Who Owns the Nation's Minerals?

There is little information on the quantities of minerals in public and private ownership. In part this is because relatively little is known about what minerals actually exist. Further, no agency maintains statistics on the ownership of known deposits. At best, the ownership of minerals is extremely complex and often transitory; for example, locatable minerals on federal land become private property with the filing of necessary legal papers. The key question is not one of who owns the minerals but whether they are accessible and available for development, and under what conditions.

While significant amounts of minerals are believed to lie beneath federal lands, these lands account for a relatively small proporation of domestic minerals production, indicating that large amounts of minerals are in private ownership. For example, most of the phosphate produced in Florida comes from private lands while nearly all the iron ore produced domestically is mined on private land in Minnesota's Mesabi iron range.

There is some information on the federal government's ownership of energy minerals, since these minerals are subject to lease. In the West, the government owns about 60 percent of the 237 billion tons of identified coal reserves (U.S. Department of Interior, Office of Surface Mine Reclamation and Enforcement 1987).

When the federal government acquired the national forests in the East, it often did not buy the subsurface minerals and while some minerals rights have subsequently been purchased by the federal government, the rights to minerals beneath large areas of the eastern national forests remain in private ownership. In the late 1970s, it was estimated that private owners hold the

rights to minerals under one-third of the 25 million acres of national forests in the East (Shands and Healy 1977).

The Nation's Energy Minerals

According to the Department of Energy, the United States in 1985 had proved reserves (quantities deemed recoverable from known reservoirs under existing economic and operating conditions) of crude oil of 28.4 billion barrels, which amounts to about a nine-year supply at mid-1980s production rates. DOE estimates that there are about 82.6 billion barrels of undiscovered recoverable crude oil (Department of Energy 1987b). Proved reserves of natural gas in 1985 amounted to 193.4 trillion cubic feet, equivalent to 34.4 billion barrels of oil (Department of Energy 1987b). Projections made for the National Energy Plan are more generous, assuming the existence of 110 billion barrels of oil and 770 trillion cubic feet of natural gas resources that as yet are undiscovered. To put these amounts in perspective, as of 1984, the U.S. had produced a cumulative total of 130 billion barrels of crude oil and 650 trillion cubic feet of natural gas (Department of Energy 1985).

The Department of Energy concludes that "Beyond 1990 [domestic] oil and gas are likely to become increasingly difficult to find and develop..." (Department of Energy 1985).

However, other experts contend that there are 300 billion barrels of oil which could be recovered, although it will require expensive new technology (Abelson 1987). The potential for development of these resources is discussed in the following chapter on supply.

The United States has abundant supplies of coal. The nation's reserves of coal are estimated to be 478.2 billion short tons (in 1985, the U.S. consumed 818 million short tons). There also are large reserves of oil shale with estimates ranging from the equivalent of several hundred billion barrels of oil, to more than a trillion barrels (Abelson 1987). The nation also has large amounts of uranium, if required for nuclear power generation. There also is the potential for increased use of geothermal resources; the Department of Energy believes that by 1995, geothermal energy sources could provide more than double the electrical power they now generates.

The Nation's Metallic Minerals

The United States possesses large quantities of many metallic minerals, although not all can be economically recovered at current prices or with available technology. The U.S. Geological Survey and Bureau of Mines have developed a system for describing the nation's minerals resources (Figure II-5) based on both geologic knowledge and the economics of minerals extraction. The two major classifications are <u>resources</u> and <u>reserves</u>. Resources encompass <u>all</u> the nation's minerals, both discovered and undiscovered. <u>Reserves</u> comprise minerals which have been discovered and may be either economic to recover given current technology, or marginally economic. The resource is considered economic if the costs of extraction and production allow the miner to profit profit financially from her operation.

The Bureau of Mines defines the <u>reserve base</u> as that part of the resource which might feasibly be mined given current mining and production processes. The reserve base includes all economic and marginal reserves, and a portion of the uneconomic reserves (U.S. Department of Interior, Bureau of Mines 1987b; Dorr 1987). The reserve base is dynamic and constantly changes because of new

Figure II-5--RESOURCES/RESERVES CLASSIFICATION SYSTEM

RESOURCES OF (commodity name)

[A part of reserves or any resource category may be restricted from extraction by laws or regulations (see text)]

AREA: (mine, district, field, State, etc.) UNITS: (tons, barrels, ounces, etc.)

Cumulative Production	IDENTIFIED RESOURCES			UNDISCOVERED RESOURCES	
	Demonstrated		Inferred	Probability Range (or)	
	Measured	Indicated		Hypothetical	Speculative
ECONOMIC	Reserves		Inferred Reserves		
MARGINALLY ECONOMIC	Marginal Reserves		Inferred Marginal Reserves		
SUB-ECONOMIC	Demonstrated Subeconomic Resources		Inferred Subeconomic Resources		

discoveries, new technology, and flux in local, national and global economies. Table II-1 displays the 1985 domestic reserve base estimates for the indicator minerals. The implications of these reserve base estimates for future supply are discussed in detail in the following chapter.

The Nation's Industrial Minerals

The nation has adequate reserves of limestone and phosphate rock (Table II-1), but lacks reserves of some important industrial minerals such as industrial diamonds. Minerals materials used in construction, such as sand, gravel, stone, and clay, are abundant on a nation-wide basis, and are widely distributed. Because of their weight and bulk, transportation is costly and as a practical matter, these materials are extracted and processed as close as possible to where they are used. While deposits typically exist near metropolitan areas, they may be rendered inaccessible by urban development (U.S. Department of Interior, Bureau of Mines 1985).

CHAPTER III. THE MINERALS SUPPLY SITUATION

HIGHLIGHTS

* For most minerals the U.S. requires, there are adequate supplies worldwide for anyone with the money to buy them.

* While world production of oil currently is in excess of demand, increased consumption by OPEC nations and political factors could reduce the amount of foreign oil available for purchase by the U.S.

* There are abundant supplies of metallic minerals worldwide, but their cost and security of supply raise questions about their availability.

* The market for many minerals is global in scope and extremely complex, and for some minerals there are frequent periods of shortages or oversupply.

* A number of minerals critical to the U.S. economy or of military importance are controlled by unstable or unfriendly governments or are vulnerable to disruption by regional conflict.

* Supplies of minerals can be extended through more efficient use, conservation, and recycling.

Minerals are traded in world markets to a far greater degree than other forest and rangeland resources and domestic reserves are only one possible source of the minerals required to satisfy the nation's needs. Thus, an assessment of minerals supplies must consider the world minerals situation. For most minerals the U.S. requires, there appears to be adequate supplies worldwide available to anyone with the money to buy them. The question is <u>where</u> the United States will get the minerals to satisfy its needs, and at what price.

World prices for a mineral affect the economics of exploiting domestic reserves. U.S. self-sufficiency may be achievable from a technical point of view, but international politics and economics weigh just as heavily in industry's decisions about minerals exploration, mine development, and production.

For minerals of strategic or economic importance which the U.S. imports in significant amounts, the critical issue is security of supplies arising from political and economic instability of the source countries, and military conflict. However, supplies can be extended through more efficient use of minerals by industry, conservation by consumers, and recycling.

How Prices Affect Minerals Supplies

The price of a mineral commodity is a critical variable in the supply calculus. If supplies are inadequate relative to demand, prices increase, thus stimulating exploration for and development of mineral resources. On the other hand, rising prices tend to cause a decrease in consumption, either through a switch to less expensive substitutes if they are available, conservation, or by deterring its use in some new product or process. The words of the U.S. Department of Energy that "...prices play a key role in balancing domestic energy consumption, production, and [foreign] trade" (U.S. Department of Energy 1985) is true for metallic minerals as well.

In a perfectly-operating market, at some price supply and demand would reach equilibrium - supply would match demand and some stability would be achieved. In the case of some minerals, particularly mineral materials abundant domestically, the market system works well and supply and demand appear to be near equilibrium. For other minerals the market does not work well and there are frequent periods of both shortages and oversupply.

The reason for this is that the market for many minerals is global in scope, and extremely complex. Decisions made by individual countries or a group of nations that controls a large portion of the world's supply of a mineral reverberate worldwide. The effect of decisions by OPEC on worldwide supply and prices of oil are well known. Organizations of major producing countries exist for other minerals as well. Even a single nation can have a significant effect on supplies and prices. Chile is the world's leading copper producer and its state-owned National del Cobre de Chile accounts for nearly 14 percent of production (Hargreaves and Fromson 1983). Thus, Chile exerts a major influence on the world copper market. Moreover, the economic objectives of other producing nations often are much different from those of the U.S. and their actions may appear unpredictable or unreasonable.

Some economically depressed countries are willing to sell their minerals at relatively low prices for foreign exchange (U.S. Department of Interior, Bureau of Mines 1985). This depresses world prices and discourages domestic exploration, development, and production.

The value of the dollar relative to other currencies also affects domestic production. A high-value dollar effectively reduces the price of foreign minerals, making them more competitive with domestic sources (U.S. Department of Interior, Bureau of Mines 1985).

Prices also affect the development of new technology to recover hard-to-exploit reserves, to convert coal to liquid fuel, to recycle, or to develop substitute materials.

Energy Minerals: The Supply Situation

Supplies of oil exist in a number of free world nations in addition to the United States. However, the nations of the Organization of Petroleum Exporting Countries (OPEC) dominate the supply picture. Three-fourths of known world reserves of are in OPEC countries, and two-thirds of the reserves are in five nations bordering on the Persian Gulf (Department of Energy, 1987a). The United States possesses only four percent of the known world oil reserves (Hargreaves and Fromson 1983). While there appears to be be significant supplies of petroleum worldwide, the long-term picture is uncertain. While OPEC nations now have what amounts to a supply surplus, this picture could change. OPEC's share of world oil production is expected to rise significantly through the rest of this century; however, consumption of oil by OPEC members is expected to triple by the year 2000, thus limiting the amount available for export (U.S. Department of Energy 1987a).

Domestic supplies of oil and natural gas are uncertain over the long-term. It appears that most of the easily-recoverable supplies of petroleum have been depleted; fields in the contiguous states have been pumped for many years, and recovery rates are declining. The average output of domestic wells in 1984 was 14 barrels a day, compared to 801 in Mexico, 4,100 in Norway, 5,341 in the United Kingdom, and 12,011 in Saudi Arabia (Abelson 1987).

There is evidence, however, that significant reserves of petroleum exist, but will be expensive to recover and require new technology (Fisher 1987). If the price of crude oil increases, investment in these resources could become attractive. In fact, the U.S. continually adds to its reserves through

technology that makes oil economically recoverable, enlargement of areas of proven reserves, and new discoveries. The nine-year reserves-to- production ratio has held at that level (or higher) for more than three decades (Department of Energy 1987a).

However, concern over potential environmental impacts has generated opposition to the development of petroleum reserves on public lands, on the outer continental shelf (OCS), and in Alaska.

Worldwide there are abundant supplies of coal and natural gas and there would appear to be no shortage of coal or natural gas for the foreseeable future. The U.S. has immense coal reserves--enough to last several hundred years. It also has significant amounts of natural gas and reserves of other fossil fuels--oil shale and tar sands--which are costly to develop but could substitute for oil. The domestic supply of uranium is sufficient to supply any foreseeable demand, and there is potential for increased development of geothermal resources.

Metallic Minerals and Precious Metals: The Supply Situation

Worldwide, there are abundant metallic minerals resources. Looking only at the indicator minerals, the world reserve base is sufficient to satisfy demand at 1985 production rates for many years (Table II-1, previous chapter). The same is true of virtually all important minerals. Although worldwide supplies of critical metallic minerals are adequate, the cost of foreign minerals and the security of supplies of minerals of economic and strategic importance raise questions about future availability of some minerals upon which the U.S.

depends. For example, 60 percent of the internationally-traded copper is controlled by the nations of the Council of Copper Exporting Countries (Chile, Peru, Zambia, Zaire, Australia, Indonesia, Papua-New Guinea, and Yugoslavia). Nearly three-fourths of the world's chromite reserves are in South Africa (Hargreaves and Fromson 1982). The issue of supply security is discussed later in this chapter.

As noted in the previous chapter, the reserve base of a mineral is constantly changing because of new discoveries, changes in the world prices, and new technology that reduces the cost of exploration and extraction. Because of this flexibility in the amount of material the reserve base encompasses, long-term supply forecasts are uncertain at best. Supply projections are limited by their dependency on current reserve base estimates.

With the exception of gold and silver, the U.S. has more than 10 percent of the world's reserve base or adequate reserves. Even in the case of gold and silver, the domestic reserve base is not insignificant. Nonetheless, the U.S. supplements domestic production of four of the indicator minerals (copper, lead, gold, and silver) with foreign imports. Dividing the reserve base quantities by 1986 consumption levels, it appears that the U.S. reserve base for copper, lead, gold, and silver will be exhausted in less than 50 years. Comparing production to reserve base for a number of minerals, Cameron (1986) has concluded that "...the U.S. mineral position is weak with respect to a number of important minerals" and unless production (and consumption) fall or new reserves are discovered the nation's minerals position "will become significantly weaker through 2005."

However, reserve base estimates should be evaluated with caution, particularly when calculating long-term supply trends. Cameron's data do not mean that the nation is running out of minerals, only that increased exploration and development will be required to maintain equilibrium between production (consumption) and supply. Supply generally increases with a rise in demand. How this dynamic works is illustrated by the case of gold. With a strong demand for gold in the mid-1980s, about 80 percent of all funds invested in minerals exploration in the U.S. focused on that precious metal (U.S. Department of Interior, Bureau of Land Management, Undated). More than 40 new mines were opened nationally in 1986. Moreover, changes in world prices or more efficient mining and processing technologies could make current uneconomic reserves profitable to develop or stimulate the exploration for new reserves. For example, using new processing techniques, industry today is extracting copper from low-grade ores that once were not economic to mine.

In some cases, even deposits that are likely to remain sub-economic should be counted as part of the nation's long-term supply. For example, the Bureau of Mines reports progress in recovering manganese -- a vital steel alloy that the U.S. imports from South Africa -- from several plentiful but low-grade domestic deposits. While not now economic to produce, these deposits could serve as an emergency source (Federal Emergency Management Agency 1987).

Moreover, abundant supplies of many minerals are known to exist on the seabed, although they cannot now be recovered economically (U.S. Department of Commerce, National Oceanic and Atmospheric Administration 1987). Because of the strategic importance of some of these minerals (especially manganese), the

Bureau of Mines is conducting research on deposits on the ocean beds controlled by the United States, as well as recovery technologies (Federal Emergency Management Agency 1987). It is possible that these off-shore deposits could become economic to recover during the 50-year period covered by this Assessment.

Minerals Materials: The Supply Situation

Because of their weight and bulk, minerals materials used for construction typically are mined near the area where they are to be used. Thus, domestic supplies, not foreign supplies are the critical factor. Nationally, the U.S. has sufficient supplies of minerals materials, although there are local areas where minerals materials used in construction, such as sand and gravel and rock aggregate, do not occur or occur only in limited amounts. When local supplies are exhausted, the materials must be delivered from a distance -- at increased cost to the consumer. Sand and gravel is hauled by unit train from Montana to North Dakota where the material is in short supply (LaMoure 1988). In those areas where supplies of mineral materials exist, land use and environmental constraints are major factors affecting supply. (U.S. Department of Interior, Bureau of Mines 1985).

For limestone, supply and demand essentially is in equilibrium, although domestic consumption has slightly exceeded domestic production since the mid-1970s. The U.S. has abundant supplies of phosphate rock and produces a surplus for export.

Recycling: Another Source of Supply

The United States currently recycles a relatively small proportion of the minerals it consumes; most is lost in the waste stream (Table III-1). However, in the case of a few minerals, recycled material is an important domestic

Table III-1--Recycling of non-fuel minerals as a percent of consumption

Commodity	Units	Amount Recycled	Apparent Consumption	Percent
METALS				
Aluminum	1000 mton	830	5291	16
Copper	1000 mton	479	2136	22
Gold	mil. oz.	1.4	3.3	42
Lead	1000 mton	540	1100	49
Molydenum	Recycled as a component of steel scrap independent of molybdenum content.			
Silver	mil. oz.	17	168	10
Tin	m tons	11000	60568	18
MATERIALS				
Limestone	"Large quantities" are regenerated by industry.			
Phosphate Rock		NONE		
Sand and Gravel	Road and concrete surfaces on a limited, though increasing basis.			

NOTE.--The meaning of the term "recycling" changes depending on the commodity discussed. Here, recycling refers to the quantity of material recovered from discarded products and old scrap not generated by current operations. This definition limits the contents of the recycling bin to material which must be substantially converted and refined through what are usually caleed "secondary production" processes.

Sources: U.S. Department of the Interior 1987b, 1988

source. For example, there is no real domestic source of tin, yet in 1986, about 20 percent of the 45.7 million metric tons consumed came from recycled material (U.S. Department of Interior, Bureau of Mines 1987b). Some 50 percent of lead consumed domestically came from recycled material -- primarily auto batteries.

Recycling is affected by many of the same factors that influence the development and processing of an in-ground mineral deposit: the price of reclamation relative to purchase of new supplies; degree of concentration of a mineral in waste; and available recycling technology.

The Nation's Strategic Stockpiles

The United States has established stockpiles of petroleum and some critical metallic minerals to assure their availability in case of an interruption of foreign supplies. However, this is costly and contributes to the budget deficit. Moreover, when supplies are only available from foreign sources (or in the case of oil, require increased overseas purchases) acquisition contributes to the foreign trade imbalance. Thus the stockpiles are built at variable rates.

The nation has established a Strategic Petroleum Reserve goal of 750 million barrels of oil. As of December, 1986, the reserve's oil inventory amounted to 511.6 million barrels. An average of 51,430 barrels a day were added to the reserve during 1986 (U.S. Department of Energy 1987f). The Omnibus Budget Reconciliation Act of 1986 required that the reserve be filled at the rate of 75,000 barrels a day. The 1987 Act did not require a specific fill rate.

Instead, the fill rate is based on the budget for FY 1988. The Strategic Petroleum Reserve was appropriated $438.7 million dollars, $256.4 million of which are used to fill the reserve. The average daily fill rate of about 50,000 barrels is based on the latter amount. The National Defense Stockpile of non-energy minerals and some other strategic materials has excess inventory over goals in some minerals, but these are outnumbered by inventory deficits.

The Security of Foreign Supplies

A number of minerals critical to the U.S. economy or of strategic importance are controlled by unstable or unfriendly governments or are vulnerable to disruption by regional conflict. Thus, of equal concern is the assurance of supply and this nation's vulnerability to long- or short-term disruptions. As discussed earlier in this chapter, two-thirds of the free world's known oil reserves are held by Mid-East OPEC nations bordering on the Persian Gulf. In 1987 and 1988, oil tankers and port facilities were the targets in the war between Iran and Iraq. Several countries are constructing pipelines to Red Sea and Mediterranean Ports to provide oil shipping outlets less vulnerable to attack (U.S. Department of Energy 1987b). Nonetheless, Mid-East oil supplies remain uncertain in a region where oil is seen as a military and political weapon and a small number of countries control the bulk of the free-world's supply.

A similar situation exists for some critical metallic minerals, precious metals, and minerals materials used in industrial processes. D. Hargreaves and S. Fromson have developed a complex system for evaluating the vulnerability of supplies of 38 minerals of strategic importance to industrialized nations

(Hargreaves and Fromson 1986). Factors evaluated include stability of the government of producing nations, probability of armed conflict, and vulnerability of transportation routes. Table III-2 shows the ten minerals which Hargreaves and Fromson ranked highest in strategic risk, the major producing countries, and U.S. import reliance as of 1986. As the chart indicates, of the ten minerals ranked highest in strategic risk, the U.S. in

Table III-2--Minerals high in strategic risk*, major producing

Mineral	Risk rating	Producing Nation(s)	U.S. Import Reliance (1986)
Chromium	41.5	South Africa, Zimbabwe	75
Manganese	36.7	South Africa, Australia	100
Cobalt	35.3	Zaire, Zambia	94
Copper	28.8	Chile, Peru, Philippines, Zaire, Zambia	28
Platinum Group	28.8	South Africa, Canada	92
Gold	26.4	South Africa	46
Aluminum	23.0	Guyana, Indonesia	16
Columbium	22.3	Brazil, Canada, Nigeria, Zaire	100
Tin	21.8	Bolivia, Indonesia, Thailand, South Africa	72
Diamond (industrial)	19.0	Botswana, Namibia, South Africa, Zaire	92

* Strategic risk index figure is based on a calculation of the likelihood of a supply disruption and its potential economic cost. An index figure over 25 is considered high risk, 10-25, medium risk.

Sources: Hargreaves and Fromm 1986; U.S. Department of Interior, Bureau of Mines 1987.

1986 imported more than three-quarters of domestic consumption of six of them. Two of this assessment's five indicator metallic minerals--copper and gold--are rated high in strategic risk. The others, lead, molybdenum and silver are either relatively abundant, or available from secure sources of supply.

CHAPTER IV. HOW SUPPLY COMPARES TO EXPECTED DEMANDS

HIGHLIGHTS

* Domestic consumption of minerals of all kinds will increase.

* The U.S. has sufficient supplies of many of the minerals it requires, although it will continue to rely on foreign sources for some minerals of economic and strategic importance.

* Where the U.S. get the energy and metallic minerals it consumes will depend to a large degree on the cost of domestic exploration and recover versus overseas prices.

* While the demand for metallic minerals will increase moderately overall, new technologies will stimulate the demand for some minerals and reduce consumption of others.

Demand forecasts indicate that compared to today's levels of consumption, the U.S. will require increased supplies of cost minerals through the year 2040. There are ample supplies worldwide of all the minerals the United States requires. For some, though relatively few, minerals of economic or strategic importance, the U.S. will have to rely on foreign sources. However, most minerals, even those the U.S. imports in significant quantities, are or could be produced domestically in amounts sufficient to satisfy domestic demand if the cost of domestic exploration and production is competitive with overseas sources and the regulatory climate favorable.

This chapter summarizes the information from the previous chapters which described the projected domestic demand for minerals and the U.S. and world supply situation, with a description of the likely future.

Minerals Demand: A Summary and Analysis

Demand for Energy Minerals

The U.S. demand for energy minerals will increase. What kinds of mineral resources will be used to satisfy domestic demand and where they are obtained will depend on the costs of domestic minerals relative to those available from foreign sources. Price also will be affected by technological advancements in minerals exploration and recovery.

The world price of oil is expected to increase substantially during the 1990s and into the next century. This should stimulate exploration and development of domestic oil sources, utilization of oil shale and tar sands, and increased use of domestic coal and natural gas. However, the demand for coal, oil shale, and tar sands will be influenced by the development of technologies that reduce costs and environmental effects. Public concerns over acid precipitation and other environmental problems linked to the burning of coal could stimulate governmental action that increases the cost of coal-generated electricity to the consumer, thus depressing the demand for coal and stimulating the use of oil and gas if available at reasonable prices. Geothermal resources will be developed where economically feasible. Future growth of nuclear power generation, and thus the demand for uranium, will depend on measures to reduce health and safety risks, the provision for disposal of high-level nuclear waste, and public attitudes towards nuclear power. Moreover, new technology that makes renewable, non-mineral energy cost-competitive with mineral sources could reduce the demand for energy minerals.

Demand for Metallic Minerals and Precious Metals

In general terms, the domestic demand for metallic minerals and precious metals will continue to increase. The Bureau of Mines forecasts growth rates averaging about 20 percent for selected indicator minerals through 2000. However, new technologies and new products will stimulate the demand for some metallic minerals, and reduce the demand for others. The dynamism of the market is illustrated by lead: while its use as a gasoline additive is being phased out, it is now in demand to screen radiation from televisions and computer monitors (Latimer 1987). Over the 50-year planning period, demand for any given metallic mineral is likely to be highly variable.

Demand for Minerals Materials

Demands for minerals materials used in industrial processes and construction are likely to follow trends in population growth and gross national product. Demand for fertilizer minerals could be affected by new farming techniques and overall demand for agricultural commodities that the U.S. produces.

The Minerals Supply Situation: A Summary and Analysis

Supplies of Energy Minerals

Overall, there will be no shortage of any energy minerals worldwide, although the price of oil is expected to increase significantly. The U.S. has ample supplies of mineral resources that could serve as alternatives to oil--natural gas, oil shale, tar sands, uranium for nuclear power. Likewise, there are opportunities for increased use of geothermal resources to generate electricity.

Supplies of Metallic Minerals and Precious Metals

The United States has supplies of many metallic minerals and precious metals sufficient to accommodate domestic demand through the Assessment period. However, the United States does not have supplies of some metallic minerals of economic and strategic importance and will have to continue to depend on foreign sources. For those minerals which are present in the U.S., the cost of foreign supplies vis a vis the cost of domestic production largely will determine the extent to which domestic demand is satisfied by domestic supplies. Restrictions on minerals production from federal land, and environmental concerns could limit domestic supplies of some minerals. For some minerals that the U.S. imports in significant quantities, the availability of overseas supplies will be influenced by factors unrelated to the physical existence of the resource, such as global and regional politics and the stability of the government of the producing country.

Supplies of Minerals Materials

The domestic supply of minerals materials used in construction historically has been in equilibrium with demand and no national shortage is anticipated. However, local deposits of mineral materials used in construction could become depleted, resulting in rising costs to consumers for transport of needed materials from distant areas.

Price/Cost and Supply Interactions

As discussed in the previous chapter, the price of a mineral--or its cost in world markets--influences supply as well as demand. Higher prices stimulate

domestic exploration, development, and production of a mineral--increasing supplies, but with increased costs to consumers. Similarly, rising prices serve as an incentive to increased utilization of existing reserves, more efficient use of raw materials in manufacturing, a switch to less expensive substitutes, and consumer conservation.

Other economic factors not directly related to minerals also will influence minerals consumption and demand. These include efforts to reduce the federal deficit (seen in reductions of additions to U.S. strategic stockpiles), need of foreign countries for cash, value of the dollar relative to foreign currencies, and U.S. balance of trade. Interest rates, federal and state tax policies, the price of labor, and the cost of environmental protection, all affect the competitive position of the domestic minerals industry, and consequently, amounts of domestic minerals consumed and demands upon domestic resources.

The Future

Ways in which the nation's minerals needs are satisfied -- either through increasing or extending supplies -- shift as the national and world economic situation changes and new technology is brought on line. This will continue. In terms of increasing the quantity of minerals available domestically, trends seem to indicate the following:

- There will be a continued reliance on foreign sources to supplement domestic supplies for both energy and metallic minerals, when the price of overseas minerals is less than the cost of producing them domestically;

- Rising prices for fossil fuel energy minerals worldwide will stimulate increased exploration for and production of domestic energy sources, with prices significantly higher than they are today, and there will be increased reliance on domestic reserves of coal;

- Domestic production of metallic minerals will rise as new exploration and recovery technologies make domestic minerals cost-competitive with foreign sources.

- There will be a growing demand for industrial minerals, especially materials used in construction.

The following chapter considers the social, economic, and environmental implications of these trends, emphasizing increased domestic production.

CHAPTER V. SOCIAL, ECONOMIC, AND ENVIRONMENTAL IMPLICATIONS OF THE SUPPLY/DEMAND COMPARISONS

HIGHLIGHTS

* There is likely to be increased domestic minerals production to satisfy demand, although the U.S. will continue to import significant amounts of some minerals it requires.

* The national economy will benefit from increased domestic minerals production through reduced imports and the mining industry's increased contribution to the nation's gross national product.

* Greater domestic production will have both positive and negative regional and local economic and social impacts. Positive effects will include increased jobs and higher incomes. Negative effects include the need for government investment in facilities and services; some shortages, probably short-term, in services and housing; and changes in the social structure, politics, and culture of small rural communities.

* Potential environmental impacts include changes in lands and soils, aesthetic degradation, and adverse impacts to water quality, and fish and wildlife habitat.

The comparison of demand and supply in the previous chapter indicates that there is likely to be increased domestic production to satisfy demand. The U.S. will continue to import some minerals either because they cost less overseas or because no economically exploitable domestic deposits have been discovered. Increased domestic minerals production will contribute to the health of the national economy, but the economic, social, and environmental consequences will be most evident in communities where the mineral activity occurs. Greater reliance on imported minerals also would have important national economic impacts and affect regions and localities as well.

Effects at the National Level

Encouragement of domestic minerals production would benefit the national economy in at least two ways:

First, the nation's balance of trade with foreign countries will improve as U.S. industries use more domestic minerals. Presumably, imports will decline if domestic prices are favorable. If there is a production surplus, exports might increase as well. This will have a beneficial effect on the nation's economy generally.

Second, the economic climate for domestic minerals industries will improve, thus increasing their contribution to the gross national product (GNP).

Alternatively, increased minerals imports will aggravate the nation's already serious international balance of payments deficit. The situation will be especially acute in the case of oil. While the nation enjoyed relatively inexpensive foreign petroleum in the mid and late 1980s, experts generally agree that low foreign oil prices are not likely to last beyond 1990, and prices will rise significantly in the next century (Department of Energy 1985). If present import trends continue, the national bill for foreign oil could amount to $200 billion by the year 2000, about half of the total foreign debt in 1987 (Abelson 1987). This would place a heavy burden on the national economy.

The net import of minerals on the health of the U.S. economy, however, depends in part on the price of the imports. As long as the price of foreign minerals remains low, and other sectors of the economy are relatively vigorous, the national economic effects of increased minerals imports might not be significant. Although the domestic metallic minerals industry's share of the GNP declined between 1981 and 1985, overall GNP rose (U.S. Department of Commerce, Bureau of the Census 1986). Increased imports of relatively cheap foreign oil actually helped keep inflation in check.

Dependence on imports could have serious consequences during time of rapid price increases though. To the extent that the nation's reliance on foreign sources renders the domestic minerals industry unable to rapidly initiate or expand production, the national economy could be stressed by disruptions in foreign supplies or significant price increases. To a degree, this is what happened in the case of OPEC oil in the early and mid-1970s.

The social and environmental effects of increased domestic minerals production will be widely dispersed and probably will not be apparent at the national level.

Effects on Regions and Communities

Increased domestic production can be expected to have both positive and negative regional and local social and economic impacts. Those impacts will be primarily focused in the areas where the minerals activity is occurring. Increased on-shore oil and gas production is most likely to effect parts of

Alaska, the northern Rocky Mountains, and the Southwest, while increased domestic coal production primarily will affect localities in the Appalachians and coal regions of the upper Great Plains. Increased domestic metallic minerals production will impact relatively few areas, primarily in the West, and the iron ore producing areas of the upper Great Lakes. Although larger mineral operations have greater potential social, economic, and environmental effects, there are few very large metallic minerals mines; of the 296 metallic mineral mines in the U.S. in 1985, only 121 produced more than 100,000 tons (U.S. Department of Interior, Bureau of Mines 1987a). Increased demand for industrial minerals, especially those used in construction, will result in greater numbers of quarries near growing cities and communities throughout the country. These also tend to be relatively small operations; the vast majority of the more than 6000 sand and gravel quarries in the U.S. in 1985 produced less than 100,000 tons of material a year.

Economic Effects

Increased domestic production will have both positive and negative effects in regions and localities where minerals development takes place. Positive effects will include increased direct employment in the minerals activity and higher personal incomes. That increase in direct employment will also lead to expansion of secondary jobs and income in the retail sales and service sectors. Increased state and local tax revenues will result from the increases in the direct and secondary employment stimulated by the minerals development. There are also likely to be some negative economic impacts in the short-term. State and local investment will be required to pay for additional facilities such as roads, water supply, and sewers, and public services such as police and fire

protection, schools, hospitals, and recreation. Shortages in some facilities and services can be expected in the short-term, although these probably would be corrected over time. Recent legislation in some states, such as Montana and Wyoming, require the minerals developers to finance some of this new social infrastructure through prepayment of taxes (Montana code annotated 75-20-101 to 1205, Wyoming Statute 35-12-101-121). Established residents may face increased costs for housing and some other goods because of increased demand by new residents. Other sectors of the local economy, such as agriculture, may also face higher costs for resources such as water and labor because of the increased demand stimulated by the mining activity. Ultimately, there will be some financial stress when depletion or market changes lead to closure of the minerals development.

A number of factors affect the balance of adverse and beneficial economic effects. The size of the mine and value of the mineral being mined, the number of workers employed and skills required; the pace of development; and duration of activity all influence the nature of local economic effects and the balance of adverse and beneficial impacts (Wenner 1984). The policies of the developing company, such as hiring local people and buying in the local economy, can affect the economic fortunes of the affected community. Large mining companies are making deliberate efforts to maximize local economic benefits and to establish cooperative relationships with local communities to ensure their needs are addressed (ASARCO 1983).

Similarly, the characteristics of the local community affect a locality's ability to accommodate increased economic growth (Wenner 1984). Factors

include size of the community, degree of isolation, the ability of local governments to cope with growth, opportunities for advanced planning, business sector capability, the local labor supply, and whether the economy is diversified or based on a single sector, or whether the economy is stable or depressed.

In some cases, increased national reliance on foreign sources of minerals will cause domestic mines to close, resulting in loss of jobs and the depression of local economies in communities or areas where minerals production is a major element of the regional or local economy. For other communities, the loss of a market for domestic minerals to overseas sources will mean a lost opportunity to realize economic growth and diversification through development of local minerals resources.

Whether the decline of a local mine, or its closure results in a net loss to the community in the longrun depends largely on the availability of other economic opportunities in that community. Other sectors of the economy may expand and compensate to some degree for lost minerals activity. Some port cities probably will realize economic benefits from increased minerals imports. Consumers could also benefit from imports if those imports are lower priced than domestic sources.

In summary, the national economy can be expected to improve as a result of increased production of domestic sources. Regional and local economies will benefit from increased employment and income but also will be stressed to provide facilities and services for greater numbers of workers and their

families. Increased imports, on the other hand, will contribute to problems at the national level; including increases in the nation's international trade deficit, although consumers may benefit from cheaper imported goods. Increased imports would stress some local communities if domestic mines close because they are not cost-competitive with foreign supplies.

Social Impacts

As in the case of economic impacts, the development of domestic mineral resources can be expected to generate both positive and negative social effects. Increased economic activity and employment can generate feelings of social well-being. New jobs will also make it possible for young people to remain in the locality. New employment opportunities may attract an influx of workers and their families with resulting changes in the social structure, politics, and culture of small rural communities (U.S. Department of Agriculture, Forest Service 1980). This influx may lead to friction between newcomers and established residents, especially if they differ in culture, education, and economic status. A swiftly-increasing population will stress schools, health care systems, law enforcement and social services. Over the long-term, however, a larger population will stimulate improvement in social services, medical facilities, schools, and cultural and entertainment opportunities.

Some communities are more capable than others of assimilating new people and meeting increased demands for housing and social services. The vulnerability of a community to social disruption depends on many of the same factors that affect its ability to deal with economic change. Generally, communities that

suffer economic stress also will have difficulty adjusting to the social demands of large-scale minerals development.

The regional and local effects of increased imports of foreign minerals at the expense of domestic production also will be mixed. If foreign imports result in the closure of domestic mines, there will be stress on individuals who lost their jobs. These individuals would have to move to other areas for new opportunities, take less desirable jobs in the same locality, or accept public welfare, at least in the short term.

In summary, the social effects of increased domestic production will be felt mainly at the regional and local levels. Social benefits are related to increased jobs and higher incomes, and improved social services and cultural and educational opportunities over the longer term. However, there are likely to be adverse effects, especially in the short-term, because of increased costs to local governments, social stress that accompanies rapid, unplanned growth, and changes in the character of local communities.

Environmental Effects

Increased domestic minerals production has the potential for adverse environmental effects in the areas where minerals development occurs. Increased use of foreign minerals will result in less environmental concern in this country, although the direct environmental effects of the minerals development will be transferred overseas, often to developing countries where environmental standards are far less stringent than in the U.S.

The nature and severity of potential environmental effects depend on a number of factors. Among them are the ecological character of the land being developed, the mineral being mined, methods used to extract and concentrate the ore, technology available to mitigate adverse impacts and whether or not it is used, the policies of the mining company, and the enforcement of mitigating measures by local, state, and federal entities. Many laws have been enacted and regulations promulgated to address the environmental impacts of mining. Enforcement at all levels could effectively mitigate many of the significant effects such as those experienced in the past.

Some environmental effects are quite site-specific, such as storage of mine tailings, while other have broader regional effects, such as water pollution or the disruption of wildlife.

Environmental effects also have varying durations; while some effects are greatest when the mine is active, others, such as changes in the landscape and toxicity of mine waste, can persist long after mine operations cease. Often, post-mining effects -- particularly water pollution -- are the most difficult to mitigate (National Research Council 1979; U.S. Environmental Protection Agency 1985).

The U.S. Environmental Protection Agency (1987) studied 31 "environmental problems", including mining waste. Mining waste was rated in four categories of environmental risks and was found to be low in non-career health risks and welfare effects; moderate in cancer risk; and high in ecological risk.

While environmental degradation is inevitable, particularly in the short-term, there are measures which can be taken to avoid or mitigate most of the adverse environmental effects (U.S. Environmental Protection Agency 1985; PEER Consultants 1984). Enforcement of federal, state and local environmental quality laws will prevent some of the most serious adverse environmental effects. For example, the Surface Mine Control and Reclamation Act (SMCRA) provides for federal incentives to states to regulate surface coal mine operations and ensure adequate reclamation. Congress exempted mining from coverage under the Toxic Substances Control Act (TSCA) pending a study by the U.S. Environmental Protection Agency of the hazards of mining waste (U.S. Environmental Protection Agency 1985). Subsequently, EPA has studied the concern, but to date has made no recommendation regarding TSCA coverage of mining wastes. Some localities have zoning laws and regulations aimed at minimizing conflict between minerals development and other land uses. There is evidence that the mining industry has responded to the public pressure and federal legislation of the 1970's with improved techniques that significantly reduce environmental effects, such as reclaiming mined lands to make them useful for other uses (Cameron 1986).

Increased domestic minerals production will have various environmental effects on land use, soils, aesthetics, water quality and quantity, wildlife, and potentially on human health in localized areas. The most significant effects of increased domestic production are summarized below.

Increased domestic minerals development will lead to land disturbance that will at least temporarily remove the site from timber production, range forage, wildlife habitat, and recreation uses. Overall, however, the amount of land in the nation actively used for mining is relatively small -- in 1980, the last year for which figures were available, some 228,000 acres of land were actually being used for mining nationwide (Johnson and Paone 1982). For surface mining for coal, a 1984 study estimated that 73,000 acres had been "newly disturbed" nationwide, and the total disturbed area amounted to 146,000 acres (PEER Consultants 1984). The commitment of land is not large when compared to all the nation's surface, even in areas where mining activity is or has been prevalent. For example, even Kentucky, Pennsylvania, and West Virginia have had only about two percent of their total land area disturbed; and Illinois, Indiana, and Ohio have had about one percent used (Johnson and Paone 1982). Phosphate mining in central Florida has affected 166,000 acres, or 3.2 percent of the land in a seven-county area, compared to 9 percent for urban development (National Research Council 1979).

Mine sites can be reclaimed for beneficial uses, including open space, fishing lakes and wildlife habitat, and in mountainous areas of the East, level sites for playfields and housing (National Research Council 1984; Stearnes 1985). The ease and effectiveness of reclamation depends on topography, the nature of the soil, waste material, and rainfall (National Academy of Sciences 1974; U.S. Environmental Protection Agency 1985). In contrast to the past, there are expected to be relatively fewer waste dumps and tailings that resist revegetation and are left unsuitable for any human use and of little or no value as wildlife habitat.

Minerals development can affect the long-term land and soil condition. Soil compaction changes soil physiology, and soil chemistry can be altered by the introduction of toxics, both of which yield soil conditions that make revegetation difficult. It was estimated that 1.3 billion metric tons of waste would be generated by mining extraction and processing in 1985 (Environmental Protection Agency 1985). Of this, 361 million tons would be toxic or acidic to some degree, making reclamation difficult and costly.

Increased underground mining raises the potential for subsidence, while the disposal of waste on steep slopes raises the potential for erosion and slumping (PEER Consultants 1984). Increased phosphate mining in some areas will result in greater amounts of mine slimes (waste clays deposited as a slurry) which take decades to stabilize (National Research Council 1979).

Mineral development, especially waste piles that have not been reclaimed, adversely affect scenic quality. For example, coal mining in Appalachia and metallic minerals development in the West adversely affects scenic quality near the mine site. Coal mine highwalls can be seen from highways in the mountains of Kentucky, West Virginia, and Virginia; copper mine waste piles can be seen from the highway through scenic mountains east of Phoenix, Arizona. The visual impact is greatest from surface mining. Surface mining accounts for 95 percent of metallic minerals and minerals materials extracted in the United States and 99 percent of mine waste (National Research Council 1979).

Increased minerals development will raise the potential for pollution of surface and underground water by drainage, seepage, and runoff from the mine site, waste dumps, and tailings. Depending on the mineral and method of concentrating the ore runoff may contain toxics. The disposal and treatment of water laden with chemicals is a technological challenge. There is also a risk of accidental discharge of waste through failure of retention dams and pipes (National Research Council 1979). A recent study found that "only a small percentage of [metallic minerals] mines currently monitor groundwater, use run-on/runoff controls or liners, or employ leachate collection, detection, and removal systems" (U.S. Environmental Protection Agency 1985).

Water quality can also be a serious problem after mine operations cease. Subsurface contamination is a particularly difficult problem with abandoned deep mines (National Research Council 1979).

Mining will also affect the quantity of water in some areas. For example, phosphate mining in Florida has lowered the water table 40 feet, with the resulting loss of some wetlands and disruption of water flows (Natural Research Council 1979). Diversion of water for mining in the West can have an adverse effect on riparian systems.

Although mining operations are regulated to mitigate adverse effects on fish and wildlife, there will be adverse effects to some wildlife and fish because of alteration of habitats; sensitive environments such as wetlands, riparian systems, and deserts are especially vulnerable. Some wildlife species will be disturbed by the activity associated with mineral development. For example,

there is special concern about the potential effects of mining on the grizzly bear population in the northern Rocky Mountains (Matthews, Haak, and Toffenetti 1985). Mining will decrease instream flows in some areas, which will adversely affect fish and wildlife dependent on riparian habitats and wetlands. When properly reclaimed, however, some mining sites can contribute improved fish habitat and recreation opportunities. Coal mine pits in the east, for example may be transformed into fishing lakes, thus providing new habitat and recreation opportunities (Stearnes 1985).

Increasingly local, state, and federal regulators are building mitigation measures into the mining plans over which they have jurisdiction. Through these efforts, approved mining operations provide for minimizing impacts and wildlife and fish activities and habitats.

Air quality problems, which are generally localized, include wind-blown dispersion of radioactive radon gas from uranium mine ore piles, mill tailings, and waste dumps, and toxic metals from some other kinds of operations (National Research Council 1979). There will be some increased hazard to human health from mining resulting from the inadvertent release of toxics and radioactivity into surface and underground water, and wind dispersion of radioactive radon gas and heavy metals from mine sites (U.S. Environmental Protection Agency 1985).

In summary, environmental effects from increased domestic minerals production will occur primarily at the regional and local levels. While there are risks of significant effects in some regions and localities, compliance by industry

and enforcement of existing laws and regulations will continue to reduce these risks.

VI. OPPORTUNITIES FOR MEETING THE NATION'S MINERALS NEEDS

HIGHLIGHTS

* Domestic minerals needs can be satisfied by increasing domestic production, increasing imports, extending supplies, and materials substitution.

* Opportunities for increasing domestic production can be enhanced by improving the business climate, encouraging minerals production on private lands, facilitating minerals development on federal lands, and by improving information on domestic minerals location, quantity, and quality.

* Opportunities to increase imports could be improved by tax and trade measures, and bi-lateral agreements with foreign nations.

* Supplies can be extended through more efficient recovery in mining and processing, more efficient use in manufacturing and consumption, and recycling.

* There also are opportunities to substitute non-mineral materials, abundant minerals for scarce ones, and technology.

There are a number of opportunities to accommodate the projected increase in the nation's demands for minerals of all kinds over the next 50 years. They include:

- Increased domestic production;.

- Increased imports;

- Extending supplies through efficiencies in the extraction and use of minerals and recycling;

- Substitution of abundant minerals and renewable materials or technology for scarce and expensive minerals.

The U.S. currently uses all of these to satisfy its minerals needs. Oil and manganese are imported, the first to supplement domestic supplies and the latter because no economic domestic deposits have been discovered; molybdenum and construction materials are mined domestically in amounts sufficient to satisfy demand; large amounts of lead are recycled; per capita consumption of energy has declined both through more fuel-efficient autos; optical fibers (a new technology) are replacing copper in communications.

Opportunities to Increase Domestic Supplies

Market forces largely determine whether industry will explore for and develop domestic supplies or import minerals from overseas to satisfy United States demand. The role of government in stimulating domestic production is limited, yet an array of government policies -- on taxes, foreign trade, environmental protection, use of the public lands -- influence industry decisions. Governments can provide financial incentives to encourage industry to exploit domestic sources, but such measures would have to be weighed against other public social, economic, and environmental objectives. Actions which might be taken to capitalize on opportunities to increase domestic production are discussed below.

Opportunities to Improve the Business Climate for the Minerals Industry

If domestic minerals are to provide for the nation's growing demand, industry must be able to explore, develop, and ultimately sell its products at a price competitive with overseas sources. For industry, the challenge is to make exploration, extraction and processing more cost-efficient so as to offset rising costs (Latimer 1987). Industry has made substantial strides toward

reducing costs of production, and progress in this area largely will have to come from industry itself. However, governments might review tax, trade, environmental policies to see if they unnecessarily inhibit development of domestic minerals resources and constrain the working of the marketplace. Domestic production also might be stimulated by tax incentives and low interest loans, as was done in the 1950s and 1960s (McDivitt and Manners 1977).

Opportunities To Increase Minerals Production on Private Land

Decisions on exploration and development of minerals on private land rest with the mining company and the landowner. However, the U.S. Geological Survey can facilitate exploitation of minerals on private lands by increasing efforts to identify potentially-economic deposits of minerals. The Geological Survey has produced a geologic map of 17 eastern states showing the location of more than 2,200 known deposits of metallic minerals, including a number of strategic minerals which the U.S. now imports (Federal Emergency Management Agency 1987). Information needs are discussed in greater detail below.

Minerals materials used in construction, such as sand, gravel, and crushed rock, are expensive to transport and are usually mined close to where they are used. In many areas of high population growth, minerals materials vital to construction are in short supply and are threatened by urban development. There are opportunities for state and local governments to use their land-use planning and regulatory authority to divert development away from areas with minerals deposits, especially deposits of minerals materials used in construction located near expanding urban areas. For example, California has

state legislation that encourages local jurisdictions to protect high-quality deposits of statewide or regional significance (Beeby 1988).

Opportunities To Increase Minerals Production on Federal Land

Significant supplies of energy, metallic, and some industrial minerals underlie federal forest and rangelands, including lands in the National Forest System. Key factors are access to the minerals and time required to obtain the necessary approvals and permits. While industry understandably concerned about constraints on access to minerals beneath federal lands, these lands must satisfy a number of public needs and desires. Congress and land management agencies have foreclosed minerals exploration and development in some areas because non-mineral values were deemed to be higher than the volume of the mineral resources and because it was felt that minerals could not be extracted without impairing other values over the long-term. For industry, time is money; on those lands that are open to minerals exploration and development, prompt and timely procession of applications for minerals activity could facilitate exploration and develpment. The incentive to invest in domestic exploration and production also could be enhanced by removing some of the insecurity of rights to locatable minerals on public lands (U.S. Congress, Office of Technology Assessment 1979).

Opportunities to Improve Information on Domestic Minerals Resources

Greater efforts to identify areas of high potential mineralization, with some assessment of the quantity and quality of promising deposits, would have multiple benefits.

Improved information on domestic minerals reserves, their quantity and quality, and where they are located would increase the cost-effectiveness of exploration and development.

Improved information on mineral reserves would facilitate advanced planning for their development, resulting in more efficient investment of money and manpower. Advanced planning might also reduce or prevent adverse environmental, social, and economic impacts that generate opposition to some development proposals. Moreover, the identification of specific areas of high potential on public lands, might discourage the tendency toward large-scale withdrawals of land from mineral exploration and development.

For private lands, improved mapping of known deposits or areas of high potential could encourage their development as an alternative to exploration and development on public lands where the potential for conflict with other uses is higher.

A better base of information might help identify domestic reserves of minerals which are now exclusively or substantially imported. The U.S. probably possesses reserves of important minerals for which it now relies on foreign sources. For example, the nation's first platinum and palladium mine opened in Montana in 1987, decreasing U.S. reliance on South Africa for these strategic minerals (Sheppard 1987).

Opportunities To Increase Research and Development of Technology

New technology would help reduce the cost of exploration and extraction, thus making domestic minerals more competitive with foreign sources, and making some sub-economic resources economic. This is particularly true of off-shore resources and minerals in seabed crusts which cannot now be recovered economically. The Bureau of Mines and U.S. Geological Survey are now testing dredge equipment that would permit sampling of these crust deposits (Federal Emergency Management Agency 1987). The Bureau of Mines also is working on technology which would permit recovery of manganese from low-grade domestic resources in case of a supply disruption (Federal Emergency Management Agency 1987). Research also could explore ways to reduce or mitigate adverse impacts to surface resources and the environment generally, and to improve reclamation of mined lands, perhaps lessening opposition to mining as a land use.

Opportunities To Ensure Emergency Supplies of Critical Minerals

For critical minerals which are not available domestically or in short supply, domestic needs in time of disruption could be satisfied over the short-term by increasing the nation's stockpiles of minerals of economic and strategic importance. Further, the exploration for domestic supplies could be intensified in order to find economic sources and currently uneconomic reserves which could be used in an emergency.

Opportunities for Increasing Imports

For some minerals, such as oil, natural gas, and a number of metallic minerals, the nation's rising demand could be met by increased imports from foreign countries. While supplies of oil and gas from the Mid East are uncertain,

there are secure overseas sources of supply for most metallic minerals. International minerals markets and industry's efforts to reduce domestic production costs essentially will determine the extent to which the U.S. satisfies its demands by increasing domestic supplies or through imports of foreign minerals. However, the U.S. will continue to rely on overseas sources for some metallic minerals either because they are cheaper or there are no economic deposits in the United States. The U.S. could facilitate overseas imports to satisfy demand through tax and trade measures that encourage U.S. firms to invest in overseas mines, through trade policies, and through bi-national agreements to assure stable supplies from countries where the probability of disruption through government policies or regional conflict is relatively low.

Opportunities to Extend Supplies

There are a number of opportunities to extend supplies, usually with cost savings. These include more efficient recovery of minerals and utilization of lower-grade ores, more efficient use by manufacturers and consumers, and recycling.

The development and application of technologies permitting greater efficiencies in extraction and processing of the raw minerals, with a larger portion of the mineral recovered and less waste, is one way supplies might be extended. Greater efficiencies in manufacturing -- using less of a mineral and minimizing waste -- is another. Consumers too can contribute to the extension of supplies by using more efficient products, such as fuel-efficient automobiles and energy-efficient appliances.

Relatively small amounts of minerals Americans consume are recycled, although the quantity seems to be increasing. Discarded minerals amount to another supply to be tapped, thus extending supplies of raw minerals.

Opportunities To Substitute Non-Mineral Materials

The substitution of non-mineral materials, including renewable resources, also serves to extend supplies of some minerals, reserving them for uses for which which they possess special or unique attributes. New materials, combining non-mineral substances with minerals, are being developed at a rapid rate (Sousa 1987) Thus, composite materials combining ceramics and polymers with metals are increasingly replacing the traditional commodity metals such as aluminum, copper, and carbon steel. Solar energy can be substituted for energy minerals in some applications, and wood can be substituted in many uses for materials such as steel, aluminum, concrete and plastics. Substitution of renewable resources results in less energy consumed in manufacture, and less pollution.

Greater use of these strategies for extending supplies and substitution will occur if the price of minerals rise. However, use efficiencies and recycling could be facilitated through economic incentives, much as the tax credit for investments in solar collectors stimulated consumer investment in use of this renewable source of energy in the 1970s. In addition, increased research and development of conservation, recycling, and renewable resource technologies could reduce costs and environmental risk.

VII. CONSTRAINTS TO IDENTIFIED OPPORTUNITIES

HIGHLIGHTS

* Uncertainty over potential profitability deters investment in minerals exploration and development.

* Information on the nation's minerals resources is poor.

* There are perceived conflicts between minerals development and other social, economic, and environmental objectives.

* Laws, policies, and staff shortages inhibit development of minerals on federal lands.

* Cost and perceived inconvenience discourage efficient use, consumer conservation, and recycling to extend supplies.

There are a number of constraints to the opportunities identified in the previous chapter. These include uncertainties of the marketplace, lack of information about the location and quality of domestic minerals resources, the uncertainty of foreign supplies of some minerals, and the lack of technology for exploration, development, and increased efficiency of use. While significant, most can be overcome.

Constraints To Increasing Domestic Supplies Investment Uncertainty and Risk

Uncertainties of the marketplace, including price and demand volatility, deter industry investment in domestic resources. There is considerable economic risk in minerals exploration and development. Large amounts of capital are required both to find economically-developable deposits and to open a new mine. Moreover, price and demand can change significantly during the lengthy period between exploration and production. Thus, uncertainties over the potential profitability of a mine can discourage investment in domestic minerals exploration and development.

The volatility of world prices contributes to this uncertainty. World prices of most metallic minerals fluctuate widely. While not as volatile as metallic minerals, the price of oil soared in the 1970s, then fell in the 1980s as OPEC nations reduced prices and some increased exports. That foreign governments intervene directly in supply and price decisions contributes to market instability. Low prices of foreign minerals, and oversupply of some minerals have inhibited domestic production, although consumers have benefited from cheap overseas supplies. Given the high cost of finding an economic mineral deposit, obtaining required government approvals, and the time and cost in developing a mine, the instability of minerals markets is a significant obstacle to domestic minerals production.

Comparative Costs

Domestic minerals generally cost more to produce because remaining deposits are more costly to find and develop, labor costs are generally higher in the U.S. than overseas, and the industry is required by law to comply with environmental protection standards. On the other hand, U.S. industry attracts investment because of this nation's stable government and economy, and high-quality workforce. As noted in earlier chapters, industry has made significant strides in restructuring operations and utilizing more efficient technology to reduce costs and make domestic supplies more competitive with overseas sources.

Inadequate Information on the Nation's Minerals

Insufficient information on the location, quantity and quality of the nation's minerals resources are another obstacle to the realization of the nation's

minerals potential. Much of the nation has not been examined for minerals potential using modern geological and geophysical exploration techniques. Only about half of the nation has been geologically mapped in sufficient detail to provide a sound base for minerals exploration (Cameron 1986).

Public Opposition to Minerals Development

There is considerable opposition to minerals development, especially on federal lands. This stems from perceived conflicts with surface land uses, concerns over broader environmental impacts, and state and local concerns that development will impose social and economic stress in areas where the mining will take place. This has resulted in large-scale withdrawals of federal lands from minerals development, and state and local land use controls that restrict minerals activity (American Mining Congress 1987).

Inadequacies in Managing Minerals on Federal Lands

Laws, policies, and insufficient staffing all contribute to inefficiencies in the development of mineral resources on federal lands, and lost opportunities. Neither industry nor environmentalists appear to be satisfied with the current situation. Areas being challenged today include:

- The fact that certain minerals are available on federal lands at no or low cost which tends to discourage exploration on private land;

- The adequacy of existing laws to protect surface resources and the practice of withdrawing large land areas (congressionally or administratively), often out of concern that such laws are inadequate.

- The adequacy of government - provided information on mineral resources based on concern that management on minerals on federal lands should be anticipatory, rather than reactive;

- The adequacy of staffing, such as minerals geologists and other specialists, needed to plan for minerals development, analyze proposals, and administer minerals operations;

- The adequacy of the consideration given minerals in federal land and resource management planning.

The statutory framework for minerals exploration contributes to the schism in planning for minerals and planning for other resources. One analyst asserts that "For the most part, Congress has chosen to perpetuate an industry and market-oriented regime operating alongside, and many times outside, the renewable resources planning system (Berck and Dale 1984).

On public lands, uncertainty of possession and tenure also may act to deter exploration and development of minerals. In its 1979 report on the management of minerals in federal land, the Office of Technology Assessment concluded that "Tenure for minerals activities is uncertain and insecure...there is no way to obtain exploration rights secure against the government even after particular targets have been staked" (U.S. Congress, Office of Technology Assessment 1979). Moreover, OTA found that existing laws offer "weak protection against other mineral explorers."

The Absence of a National Minerals Policy

Congress has, on numerous occasions, asserted a national interest in encouraging and facilitating development of the nation's minerals resources (American Mining Congress 1987) However, there remains no clear statement of policy that describes goals or priorities for the production of domestic minerals. Minerals management is still fragmented among several federal agencies, and coordination is poor (U.S. Congress, Office of Technology Assessment 1979; American Mining Congress 1987).

Constraints to Increasing Imports

Major obstacles to satisfying the nation's minerals needs through increased imports stem from pressures on the nation's economy. The nation's balance of payments deficit has generated a national interest in using domestic materials and products whenever possible.

In addition, the supplies of some overseas minerals are uncertain because of regional conflict, unstable governments, and the supply and pricing policies of producing nations. Despite the obstacles, there remains a need to develop assured supplies of some minerals of economic or strategic importance that are not available domestically or are in short supply.

Constraints To Efficiencies in Mining, Use, and Recycling

Major obstacles to increased efficiency in mining, use, and in recycling arise from a lack of technology which would enable industry to recover a greater proportion of minerals from deposits, and economic and environmentally-sound

methods to recover a greater proportion of the base metal from ore. For increased efficiency in the use of metals in manufacturing, the major obstacle appears to be related to cost; so long as supplies of minerals are relatively cheap, there is no incentive to reduce their use in manufactured products or to reduce waste. A similar situation exists with efficiencies of use by consumers; so long as goods (and energy required to operate them) are relatively inexpensive there is no reason to conserve on their use. In the case of energy conservation equipment, the high initial cost of conversion technology and conservation devices also deters their use. A desire for convenience is another obstacle to conservation to extend supplies; disposable items, many made from minerals, are favored for their convenience. Convenience also is a factor inhibiting recycling; some consumers resist efforts to have them prepare materials for collection for recycling. Recycling also is constrained by lack of technologies for cost-effective collection and processing.

Constraints to Use of Substitutes

Major obstacles to the use of substitutes for some minerals have to do with their suitability for the job -- such as weight and durability. Relative cost, both in per-unit cost of a product and the expense of long-term operation and maintenance, also is a significant factor. While new, high-technology advanced materials increasingly are being substituted for traditional commodity metals in many uses, for some applications there are no adequate, cost-competitive substitutes for minerals. The use of solar energy, for example, is limited by climatic factors. Wood requires more maintenance than aluminum over the long-term.

VIII. IMPLICATIONS FOR RENEWABLE RESOURCE PROGRAMS

HIGHLIGHTS

* There are opportunities to increase production of minerals beneath the nation's forest and rangelands, but measures will have to be taken to ensure that minerals extraction is compatible with other uses and environmental quality is maintained.

* While private lands will provide many opportunities for minerals development, there will be increased production on federal lands, including the National Forest System.

* The Forest Service will have to be able to accommodate increased interest in minerals of all kinds on the National Forests.

* This will require improved agency minerals management capability; the integration of minerals into planning for all National Forest resources; a review of laws, policies, and regulations; and increased research on ways to develop minerals with minimum impact on surface resources and values.

An increased demand for minerals has significant implications for management of the nation's forest and rangelands. There are opportunities to increase domestic production of minerals lying beneath these lands, but increased management will be required to insure that minerals development is compatible with other uses and environmental quality is maintained.

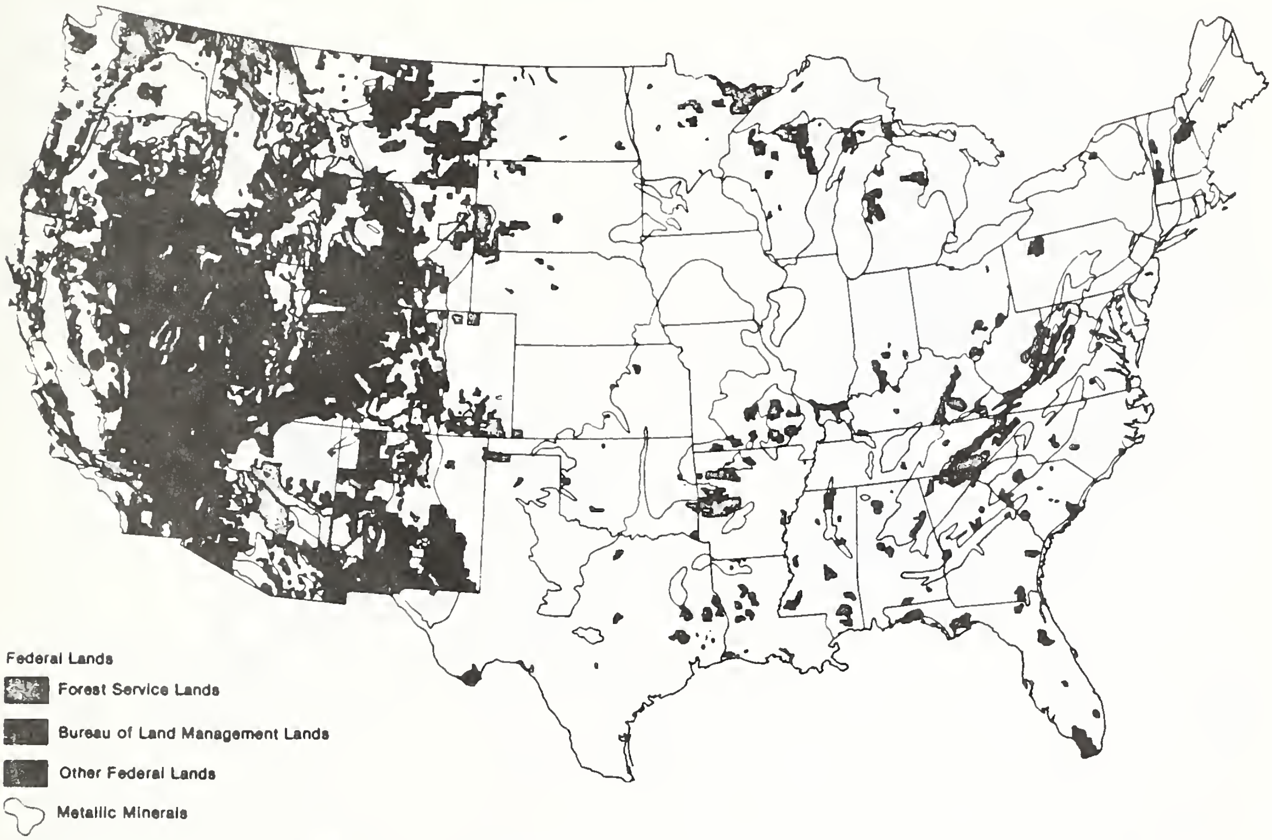
Major opportunities exist to increase minerals production from private forests and rangelands. A large proportion of current minerals production now occurs on private land, and there is evidence that major deposits lie beneath private lands in the eastern part of the country. Generally, private land is easier to access. While general environmental quality must be maintained, restrictions on minerals development generally are not as rigorous as on federal lands where the long-term productivity of other resources are a major consideration.

Increased development of minerals on private lands has major implications for federal agencies such as the U.S. Geological Survey, which is responsible for providing information on the location, quantity and quality of the nation's minerals resources, and the Office of Surface Mining, Reclamation and Enforcement, which is responsible for administration of the Surface Mining, Control, and Reclamation Act, as well as the array of state and local agencies that regulate specific land uses.

Even if private lands provide the bulk of minerals produced domestically, there is likely to be increased minerals exploration and extraction on federal lands, including the 191-million acre National Forest System. The National Forests and grasslands are generally located in major belts of mineralization, both in the West and East (Figure VIII-1,2). With some notable exceptions, the National Forests now supply a relatively small portion of the minerals produced domestically (Table VIII-1) (U.S. Department of Agriculture, Forest Service, Minerals and Geology Management Staff, 1988). However, the National Forests are major factor in the nation's production of molybdenum (69 percent of national production), gold (15.1 percent), lead (13 percent), silver (13 percent), (copper (6.4 percent), and phosphate (4.7 percent). In terms of energy minerals, the National Forests in 1986 produced 11.4 percent of the nation's output of uranium, but only 4.6 percent of its coal, 1.2 percent of the natural gas, and a minute fraction of the oil produced domestically. Production, however, is not an accurate indicator of mineral potential because access to federal lands for minerals development typically is more difficult than for private lands, and tenure less certain. It is known that 6.5 million acres of the National Forest System is underlain with coal, 45 million acres

Figure 8.1

Geographic Distribution of Metallic Minerals With Respect to Federally-Owned Lands

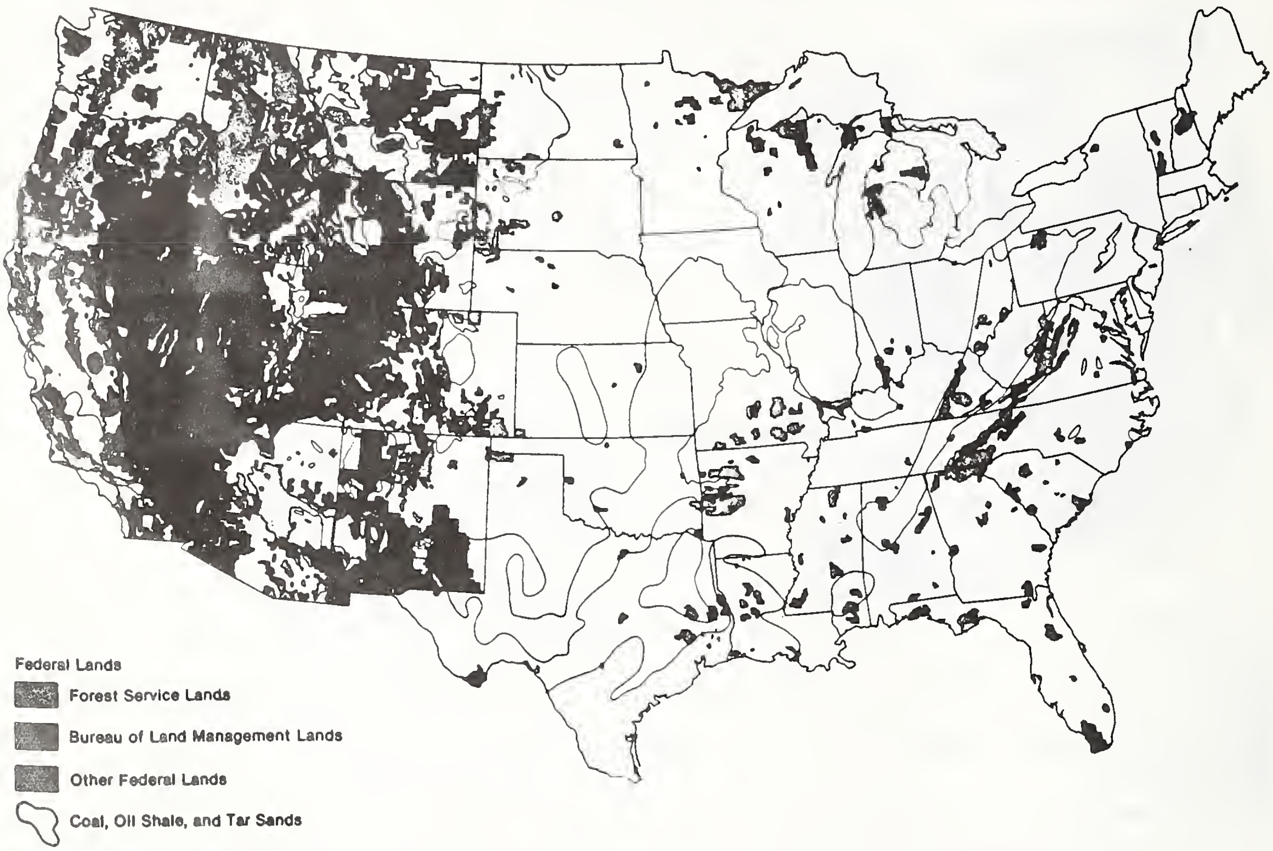


have potential for oil and gas, and 300 acres have oil shale potential. Another 300,000 acres have known phosphate potential (U.S. Department of Agriculture, Forest Service (1985) Geologically, the National Forests contain some of the most favorable host rocks for minerals deposits.

With increased demand and favorable markets, interest in minerals underlying the National Forests is expected to intensify. For energy minerals, rising prices are likely to result in increased exploration for and development of oil, gas, coal, and geothermal resources, though uranium activity is questionable. For metallic minerals, activity will continue to be

Figure 8.2

Geographic Distribution of Coal, Oil Shale, and Tar Sands With Respect to Federally-Owned Lands



opportunistic and episodic, depending on demand and world prices. Development of industrial minerals, such as limestone and phosphate rock is also likely to increase, though at a moderate pace. Where construction minerals such as crushed rock, sand and gravel exist on National Forests near expanding population centers, demand for those minerals will intensify. There also is likely to be a growing demand for crushed rock, sand and gravel from National Forests in rural areas for the construction and reconstruction of roads and highways.

Table VIII-1--Estimated production of selected minerals on National Forest land for 1986 compared to total national production.

Commodity	Units	Forest Service Production	Total Domestic Production	% production on NFS lands
Crude Oil	Mbarrels	18917	3,168,252,000	.00059
Natural Gas	MMcu f	189,663	15,991,000	1.19
Coal	M shton	41,221	890,315	4.63
Uranium	MM lbs.	1.50	13.20	11.36
Geothermal	Kilowatts	17,677	1,580,000	1.1
Lead	metrictons	223455.78	353,115	63.28
Phosphate	Mmetrictns	1814.91	38,700	4.69
Copper	metrictons	93,995.102	1,479,432	6.35
Molybdenum	M lbs.	65275	93976	69.46
Gold	Mtroyoz	563.80	3,733	15.10
Silver	MMtroyoz	4455.84	34,200	13.03
Limestone	Mshtons	1.83392	767,250,000	.23
Sand & Gravel	MMshtons	13.22350	883	1.5

Source: U.S. Department of Agriculture, Forest Service, Minerals and Geology Management Staff; U.S. Department of the Interior, Bureau of Mines 1986

In sum, the Forest Service will have to be able to accommodate an increasing interest in minerals of all kinds on National Forest System lands. For metallic minerals, given the volatility of world markets, it will be called upon to respond quickly to industry proposals when they arise. The challenge

for the Forest Service is to make minerals available from the National Forest System without compromising other uses and values.

The Forest Service's minerals mission is to "encourage, facilitate, and administer the orderly exploration, development, and production of minerals and energy resources on National Forest System lands to help meet the present and future needs of the nation" (U.S. Department of Agriculture, Forest Service 1986). Minerals activity is to be conducted in an environmentally sound manner, integrated with the planning and management of other National Forest resources, ensuring that the disturbed lands are reclaimed for other productive uses.

However, the Forest Service cannot create minerals the way it can grow trees. It can affect supply only indirectly by providing access to those minerals that underlie National Forest System lands. Its authority to do so varies according to the statutory class of minerals.

For common varieties of minerals, (such as sand, gravel, crushed rock), the Forest Service has complete discretion to dispose of these minerals as it sees fit -- it can sell them, or even give them away.

Leasable minerals (generally fossil fuel minerals in the West, all minerals on acquired land except for common varieties), are made available through decisions to lease made by the Secretary of Interior, although developers can apply for a lease for some areas where they believe minerals exist. The Federal Onshore Oil and Gas Leasing Reform Act of 1987 gave the Secretary of

Agriculture (and by delegation, the Forest Service) increased authority to regulate leasing on National Forest System lands. Previously, the Forest Service had only an advisory role, with primary leasing responsibility resting with the Department of Interior's Bureau of Land Management. The new law provides that the Secretary of Interior cannot issue a lease over the objections of the Secretary of Agriculture.

In the case of locatable minerals (generally, metallic minerals beneath public domain in the West), the Mining Law of 1872 grants miners free access to these minerals. However, later environmental laws give Forest Service some control over their development. Access is accorded through construction of roads, effective planning, increased efficiency in procession operating plans, and enforcement of environmental laws and regulations in ways that reduce public opposition and time-consuming appeals and lawsuits.

Improved Minerals Management Capability

Conflicts between minerals extraction and National Forest surface resources and uses can be reduced through improved minerals management, careful multi-resource planning, coordination with other federal agencies, state and local governments, and the minerals industry. With increased minerals activity, more technical personnel will be needed to plan for minerals development, to participate in interdisciplinary planning teams, to review development proposals and prepare environmental and social impact assessments, and to monitor minerals exploration, development, and reclamation. The Forest Service currently processes some 25,000 minerals cases annually, yet the Forest Service has only 96 minerals geologists and mining engineers (LaMoure 1988). A

resurgence of gold mining activity in the West, and the advent of new processing techniques using toxics to leach the metal from ores, will require monitoring to ensure that environmental risks are minimized. There also is a need to continue to train personnel with overall responsibility for managing National Forests in minerals management so as to better integrate use of minerals resources with management of surface resources, uses, and values.

Integrating Minerals into Land and Resources Planning

The prospect for increased minerals development on National Forest System lands will require improved planning for minerals exploration and development and their integration into planning for all the National Forests' resources and uses.

While it occurs, minerals development displaces some uses of the National Forest surface, and requires that choices be made in the allocation of resources. Thus there is the need for information about the value of the mineral resource, and the value of surface resources and uses so that comparative values and tradeoffs can be evaluated by the Forest Service and the public. To ensure that these values are adequately considered, and future options not arbitrarily foreclosed, minerals development should be fully integrated into National Forest land and resources management plans. Integrated planning should minimize impacts to surface resources and uses and environmental risks. With careful planning, uses of surface resources can take place as mined land is reclaimed.

Improvements in the Legal and Administrative Framework

Improvements in the legal and administrative framework for minerals management will be required. These include a review of regulations to ensure that they are adequate; assignment of full minerals management authority to the Forest Service for the land it manages; and improved procedures for coordination with states, localities, and the minerals industry.

Research Needs

Increased Forest Service research on the economic, social, and environmental impacts resulting from minerals development will also be required so adverse effects can be avoided or mitigated, and positive benefits enhanced. Research needs include:

- Methods of exploring for and extracting minerals with minimum impacts on surface resources and maintenance of environmental quality.
- Ways to avoid adverse economic and social impacts and to enhance benefits.
- Techniques to improve reclamation of mined lands.

Alternative Futures

In order to test the sensitivity of possible RPA Program responses to changing future conditions, the implications of nine alternative futures for U.S. minerals demand and supply are discussed below. It should be emphasized that under any of the alternatives, all minerals would not be affected equally; there would be considerable disparity in the effects on energy, individual metallic minerals, and minerals materials.

The Projections of This Assessment--Rising prices for energy and metallic minerals will stimulate exploration for and development of domestic minerals resources, including lower-grade deposits now deemed uneconomic. However, increased prices also will stimulate industry to mine and process minerals more efficiently in order to increase production, reduce waste, and cut costs. Rising prices should also result in more efficient use in manufacturing and consumption. While demand for most minerals will continue to grow, it will be moderated by increased use of advanced composite materials and less use of the traditional commodity minerals, greater use of renewable resources, and more recycling.

Improved Productivity--As noted above, rising prices will stimulate increased productivity in mining and processing. Industry will leave less of the mineral in the ground, and recover a greater proportion of base metals from ores. New technology will improve recovery of minerals and permit the economic recovery of lower-grade deposits.

High Exports of Minerals--Rising world prices for minerals, regional conflict and political instability of source nations, and improved measures that make domestic minerals cost-competitive with overseas sources could stimulate increased U.S. minerals exports. This would result in some increased domestic exploration and development. However, for most minerals, exports would represent only a moderate increase in overall demand for domestic resources.

Shortfalls in Discovery of Domestic Minerals--The United States has exploited its easily-discovered, easily recovered minerals resources; those remaining generally are of lower-quality and more difficult to access using conventional technology. The patterns is most apparent in the case of oil reserves in the Southwest, where expensive technology is required to exploit remaining oil. Shortfalls in the discovery of domestic minerals could be met with intensified exploration for hard-to-find deposits, development of lower-quality deposits, increased exploration on federal land, and increased investment in new exploration and extraction technology.

Intensified Minerals Management on Public and Private Lands--There are opportunities for intensified minerals exploration and development nationally. As discussed in earlier chapters, a number of promising deposits have been identified in the eastern U.S. Major opportunities exist on federal and private land in the West as well. Whether these opportunities will be exploited will depend on the world price of individual minerals, and the cost of exploiting available domestic reserves. Opportunities to exploit minerals on federal lands will be affected by the designation of additional wilderness areas, the allocation of other lands for specific uses under the new National Forest land and resource management plans, and availability of staff to manage minerals.

Changes in Land Uses That Foreclose Minerals Development--Expanding urban areas, the designation of additional wilderness, administrative constraints on minerals development on federal lands, and state and local land use controls could sharply reduce the amount of land available for minerals development.

This would result in more intense pressure on lands open to exploration and development, and possibly a reduction in overall domestic production. Urban expansion could significantly affect the availability of construction minerals on private land, increasing the demand on (and value of) deposits on federal lands close to metropolitan areas. Sand, gravel, and crushed rock would have to be transported longer distances, increasing costs to consumers.

Greater Environmental Constraints on Federal Lands--The production of commodities -- timber, minerals, range forage -- are affected by increasing public interest in non-commodity uses and values of federal lands. Growing non-commodity and environmental concerns could sharply reduce the production of minerals on federal lands. This will require that the Forest Service be able to integrate minerals development with other uses of the National Forests and needs to protect the scenic, recreation, water quality, and wildlife values and maintain the quality of the forest environment.

Reduced Consumption of Minerals--A number of developments in combination could reduce the demand for some minerals, particularly gas and oil, uranium, and some of the traditional metallic minerals. Possible developments include a significant rise in world prices of individual minerals, greater use of high-technology composite materials, environmental and safety concerns, the use of renewable resources, and recycling. However, while demand for some minerals would fall under this scenario, the demand for others -- particularly specialty metals such as the platinum-group metals, gold and silver, magnesium, and titanium -- would rise substantially.

Increased Consumption of Domestic Minerals--Events could occur which would result in increased demand for some domestic minerals. If, for example, foreign oil-producing nations agreed to a sharp reduction in production, the resulting rise in prices could stimulate increased production and consumption of domestic oil. Political instability or social unrest could cut off supplies of some other important minerals, increasing U.S. reliance on domestic supplies. This would result in increased exploration for and development of domestic supplies, and the development of new technology for the recovery and processing of sub-economic reserves of critical minerals.

Policy Questions for Forest Service Programs

The implications of this analysis of the minerals situation in the United States raises a number of public policy issues for the Forest Service. They can be expressed in terms of five questions.

1. To what degree should the Forest Service encourage the exploration for and development of minerals -- especially metallic minerals -- on the National Forest System?

Historically, the Forest Service has done little to explicitly encourage minerals development on the National Forests. The 1872 Mining Act declared the federal domain open to legitimate metallic minerals exploration and development, and Forest Service policies and program have been aimed at accommodating mining activity. Generally, the Forest Service has sought to maintain access to National Forest lands for minerals development, but made no overt moves to encourage their exploitation. Since manufacturers draw from

both domestic and overseas sources largely influenced by price, consumers generally benefit by getting the least-cost product. However, by encouraging and facilitating minerals development on the National Forests, the Forest Service might help reduce price volatility in some market situations.

There are actions the Forest Service could take to both encourage and facilitate minerals development on the National Forests. The Forest Service could, for example, delineate lands of high minerals potential as special "minerals zones" in National Forest land management plans. In these zones, minerals would be considered the primary value, much as recreation is determined to be the primary value of some areas. It could increase staff capability and develop procedures to expedite reviews of mining plans and the granting of necessary permits and approvals.

There is, however, substantial and growing opposition to the mining of metallic (and energy minerals) on the National Forests. Opponents contend that mining diminishes the value of large areas for other uses and create significant environmental problems. These interests want even tighter controls on minerals development on the National Forests.

The emphasis to be given minerals development on the National Forests should be addressed in the RPA Program.

2. Should miners be required to pay fair market value for minerals on the public lands?

Under terms of the 1872 Mining Law, discoverers of metallic minerals located on applicable federal lands pay no fee or other payment to the federal government. For energy minerals, the federal government receives revenue from leases of the land and royalties on minerals extracted based on rates set by the Department of Interior. The Forest Service is authorized to charge whatever it believes appropriate for common variety minerals, and charges vary widely among National Forests. A policy to charge fair market value for minerals extracted from federal land would have a number of effects. One, it could discourage some minerals activity on federal land, an effect which would be applauded by opponents of mining on the National Forests. On the other hand, such a policy probably would result in increased costs to consumers for some minerals. Moreover, to the extent that charges for minerals taken from federal lands made domestic minerals non-competitive with overseas sources, both the nation's gross national product and balance of trade would be negatively affected.

Major--and controversial--changes in law would be required to permit the Forest Service to charge fair market value for minerals extracted from the National Forests. However, this issue warrants further consideration in the RPA Program.

3. What should the Forest Service do to assure that environmental quality is not impaired as a result to minerals development?

Mining can have a significant effect on the quality of the environment, although technology is available to avoid or mitigate most of the adverse impacts. The Forest Service devotes considerable attention to assuring that

mining is carried out in ways that will minimize short-term impacts and result in no irreversible adverse effects to the environment. However, increases in mining activity, and the use of new technologies, require that the Forest Service have the personnel and funds to reivew minerals development plans and adequately monitor minerals extraction, processing, and mined-land rehabilitation on the National Forests. The RPA Program should address Forest Service programs aimed at protecting the environment from the adverse impacts of mining and ways to assure that manpower and funding levels are adequate for the task.

4. To what degree should the Forest Service seek to insulate local communities against the potentially destabilizing social and economic effects of minerals development?

Large-scale minerals development can have both beneficial and negative effects on communities near where the mining takes place. Usually, the negative effects occur at the outset of development, when large numbers of workers may be attracted to areas not prepared for a major population boom, and again years later as mining activity winds down and ultimately ceases, depriving a community of an establishment, and substantial industry.

Price volability in the minerals industry contributes to short-term disruptions in local economies. Prices that move substantially in a month or two result in swift and major changes in industrial activity--changes felt in terms of employment levels, income, consumer spending and property values in local economies. For example, changes in oil prices or production levels from Middle

Eastern countries provoke major and rapid changes in levels in exploration and extraction activities in "oil patch" towns in Louisiana, Texas, and Oklahoma. Changes in drilling plans affect leases and purchases of everything from rigs to drilling fluids to catering and transportation services. Employment levels and real estate prices also follow the "boom or bust" cycle. Worker mobility in the oil industry reduces community cobesion; local government service levels rarely adjust fast enough to meet needs. State economies are not immune either. Cutbacks in employment and spending increase unemployment compensation costs while reducing income from income and sales taxes. States, such as Louisiana, that levy severance taxes per parrel and per MCF see those revenues flucticate as output levels move following price changes.

It is not clear just what alternative exist for the Forest Service to assist communities in dealing with the negative social and economic effects of mining, but the issue should be addressed in the RPA Program.

5. Should the Forest Service promote more efficient use of minerals in mining, processing and manufacturing, and the use of renewable resources, substitutes, and recycling to extend supplies of minerals and reduce pressure to mine on the National Forests?

Market forces largely determine the extent to which the mining industry employs more efficient recovery and processing technologies, or the extent to which manufacturers and consumers substitute other materials or recycle. In the case of wood, the Foret Service explicitly promotes more efficient utilization of timber on the National Forests, and has research programs which are intended to

extend supplies, so as to slow the rate of increase in the price of timber products. The RPA Program should consider whether the Forest Service could play a constructive role in promoting alternatives to the use of minerals.

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